US Army Corps of Engineers
Nashville District

Upper Cumberland River Basin
Harlan Diversion Project
Harlan Kentucky
Contract No. DACW62-89-C-0092

Harlan Diversion Project Construction Foundation Report

February 1994

Construction Foundation Report
Harlan Diversion Project
Harlan, Kentucky

February 1994

U.S. Army Corps of Engineers
Nashville District
P.O. Box 1070
Nashville, Tennessee 37202-1070

Harlan Diversion Project
Construction Foundation Report

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Harlan Diversion Project

Foundation Report

1. Introduction.

1.1 Location and Description of Project. The southeastern Kentucky community of Harlan is located in a flood prone area near the confluence of three major forks of the Cumberland River. The project consists of four parallel tunnels which divert Clover Fork through Ivy Hill and away from the Harlan central business district. Each tunnel is 32 feet high, 34 feet wide, and approximately 2,000 feet long. The tunnels are reinforced by rock bolts and lined with shotcrete.

Near the upstream portals a diversion structure diverts Clover Fork into the tunnels. The diversion embankment is approximately 30 feet high, with a maximum height of 50 feet. It is 200 feet wide at the base and 600 feet long. A slurry trench and sheet pile cutoff prevents seepage beneath the embankment. A floodwall and a closure structure across a single track railroad line are incorporated into the left abutment of the diversion embankment.

Changes in the flow of Clover Fork required two highway relocations, one at either end of the diversion tunnels. Upstream, Kentucky Highway 38 was relocated away from the existing Clover Fork channel through road cuts and over a 316 feet long, two span, post-tensioned, I-beam bridge which spans the diverted channel as it enters the tunnels. On the downstream side Kentucky Highway 72 was re-built over a 450 feet long, four span, pre-tensioned, I-beam bridge which spans Clover Fork as it exits the tunnels.

1.2 Construction Authority and Project History. Initial studies for this project were authorized by the Energy and Water Development Act of 1981 (PL 96-367, Section 202.) This act authorized the design and construction, at full Federal expense, of flood control measures in the portions of the Cumberland River Basin damaged by severe flooding in April 1977.

The Supplemental Appropriations Act of 1982 (PL 97-257 of September 1982) further required that high levees and floodwalls constructed to comply with the Energy and Water Development Act of 1981 shall provide for a standard project flood (SPF) level of protection where the consequences from overtopping caused by large floods would be catastrophic. Similar language was contained in the Energy and Water Development Appropriation Bill of 1983 (HR Report 97-850 of September 1982), which also specifically directed the Army Corps of Engineers to study and design protection for several Upper Cumberland River Basin communities, including Harlan, Kentucky.

House Joint Resolution 492 (PL 98-3222 of July, 1984) directed the Corps of Engineers to implement immediately "nonstructural flood control measures such as relocation sites, flood-proofing and flood plain acquisition, and evacuation as described in the General Plan for Section 202 Program Implementation."

An Environmental Impact Statement was published in April 1988.

A sealed-bid solicitation (No. DACW62-89-B-0026) was issued on 1 June 1989 with a 2 August 1989 deadline.

On 1 September 1989 Contract No. DACW62-89-C-0092 was awarded to Grassetto USA Construction, Inc. and Incisa USA, Inc., Joint Venture, for the sum of $ 28,781,458.55. The Government Estimate was $ 31,305,500. The final construction cost, including all contract modifications, was $ 31,430,719.49. Notice to proceed was given on 21 September 1989. The originally scheduled completion date was 20 September 1992, and was extended to 7 March 1993.

The Harlan Flood Control Project Groundbreaking Ceremony was held on 9 October 1989 at the downstream portal site. Ceremony participants included Congressman Harold Rogers, Colonel James A. Ward, Colonel James King, Area Engineer J.C. McDaniels, Contractor Representative Massimo Rossi, and Harlan Mayor L.C. Howard.

1.3 Purposes of Report. This Harlan Diversion Project Foundation Report was prepared to insure the preservation of records of foundation conditions encountered during construction and of methods used to adapt structures to these conditions. The Foundation Report along with referenced preconstruction reports and construction progress reports will provide a complete record of project foundation conditions. As stated in Engineering Regulation No. 1110-1-1801, the potential uses of this Report include:

1. Planning additional foundation treatment should the need arise after project completion.
2. Evaluating the cause of stress, deformation or failure of a structure.
3. Planning remedial action should failure of a structure occur as a result of foundation deficiencies.
4. Planning foundation explorations and anticipating foundation problems for future comparable construction projects.
5. Determining the validity of claims made by construction contractors in connection with difficulties arising from alleged foundation conditions or from alleged changed conditions.
6. Serving as part of the permanent collection of project engineering data required by ER 1110-2-100, Appendix A.

1.4 Resident Construction Staff.

J.C. McDaniels........Area Engineer
Capt. Allyn Allison...Assistant Area Engineer
Ed Robertson..........Construction Representative
Charles Melton........Office Engineer
Paul A. Ross..........Geologist
Tim Shy...............Geologist
Ronnie Boswell........Materials Engineering Technician
Dan Ferrell...........Contract Administrator
Tommy Clayton.........Construction Inspector
James Forrester.......Construction Inspector
Robert Marshall.......Construction Inspector
Orville Wicker........Construction Inspector
Debbie Klinger........Secretary
Teresa Perkins........Secretary

1.5 Design Staff.

Marvin Simmons........Chief of Geology Section
John Stanton..........Geology Section
Paul Booth............Soils Section
Daphne Jackson........Soils Section
Jesse Perry...........Chief of Design Branch
Gordon McClellan......Chief of Civil-Structural Section
William Wilson........Civil-Structural Section
Buddy Abbott..........Chief of Relocations Section
Hank Phillips.........Chief of Hydraulics Section
Don Getty.............Hydrology and Hydraulics Branch
Tommy Allen...........Hydrology and Hydraulics Branch
Charles Davis.........Instrumentation and Inspection Section
Ray Hedrick...........Environmental Branch
Rob Karwedsky.........Environmental Branch
Sandra Martin.........Waterways Experiment Station
Richard Humphries.....Tunnel Design Consultant (Golder Assc.)
Don Mills.............Bridge Design Consultant (Kroboth Eng.)

1.6 Prime Contractor's Supervision and Quality Control.

Renatto Bozetti.......Project Manager
Lou Case..............Project Engineer
Hank Leatherman.......General Superintendent
Jerry Haney...........Tunnel Superintendent (1st Shift)
Roy Hill..............Tunnel Superintendent (2nd Shift)
Tom Trapp.............Chief QC & Instrumentation Specialist

1.7 List of Major Subcontractors.

Company	Responsibility
Codell Construction Co..... Winchester, Kentucky	Surface Excavations, Roads, & Diversion Embankment
London Bridge.............. London, Kentucky	Hwy 38 & Hwy 72 Bridges, Upstream Portal Nosing Concrete, Railroad Closure Structure and Floodwall
Hayes Drilling Inc......... Lexington, Kentucky	Hwy 38 Bridge Caisson Drilling
GeoCon Inc. .... Lakeland, Florida	Slurry Trench
Underground Petroleum...... Equipment Company Lexington, Kentucky	Underground Tank Removal

2. Contract Modifications Related To Foundation Conditions

No.	Date	Description	Cost
22	Sep 90	Clearing U/S Portal- Extended clearing limits uphill because portal slopes were revised.	$ 3,546
25	Nov 90	Nosing Reinforcement U/S and D/S- Install additional angled and vertical bolts, up to 40 feet long, to reinforce corners and nosings prior to blasting.	99,576
37	Apr 91	Hwy 72 Bridge Revision- Additional concrete required to provide pier footing embedment into rock.	39,925
39	Jun 91	Hwy 38 Bridge Revision- Revise caissons and wing walls because rock was lower than anticipated.	164,135
40	Jun 91	Hwy 38 Slide Removal and Trim Nosings- Remove landslide material from slope and roadway between stations 55+00 and 57+00. Trim overhanging rock from upstream portal nosings.	24,550
45	Aug 91	Trim Nosings and Additional Concrete- Trimming and additional concrete was required because nosings shifted during blasting.	119,710
56	Apr 92	Reinforce D/S portal slope and cracked shotcrete above tunnels 3 and 4.	10,634
63	Sep 92	Extend diversion embankment seepage cutoff farther into the right abutment by adding sheet pile wall section, because rock was lower than anticipated.	122,547
66	Oct 92	Remove and replace cracked shotcrete above downstream portal of tunnel 4.	35,209
76	Jun 93	Additional test blasting and engineering control for U/S portal noses; redrill pre-split holes cut off because of blasting; remove boulders outside of Hwy 38 template between stations 49+00 and 72+00.	61,541

3. Contract Quantities - Estimated and As-Built

Estimated and as-built quantities and unit prices are shown on pages 6 through 12.

PAYMENT ESTIMATE - CONTRACT PERFORMANCE SHEET

CONTRACTOR: GRASSETTO & INCISA USA (JV)
ADDRESS: P.O. BOX 669
BAXTER, KY. 40806
DATE: 25-Jun-93
CONTRACT NO.: DACW62-89-C-0092
PERIOD COVERED BY THIS ESTIMATE: 22 SEP 89 THRU 19 JUN 93

ITEM NO.	DESCRIPTION	UNIT	QUANTITY	CONTRACT UNIT PRICE	CONTRACT AMOUNT	TOTAL TO DATE QUANTITY	TOTAL TO DATE AMOUNT
9C.1	MOBILIZATION & PREPARATORY WRK	LS	1	************	2,300,000.00	1.00	2,300,000.00
2A.1	CLEARING,GRUBBING & REMOV STR	LS	1	140,305.39	140,305.39	1.00	140,305.39
2C.1	DIVERSION & CARE OF WATER	LS	1	356,465.96	356,465.96	1.00	356,465.96
2D.1	EXCAVATION	CY	380000	6.62	2,515,600.00	446,628.00	2,956,677.36
2D.2	PRESPLITTING	SF	133360	2.76	368,073.60	136,184.00	375,867.84
2E.1	TUNNEL EXCAVATION	CY	283100	34.53	9,775,443.00	283,578.20	9,791,955.25
2F.1	ROCK DOWELS	LF	1600	4.34	6,944.00	1,442.00	6,258.28
2F.2	ROCK BOLTS (SURFACE)	LF	11000	6.24	68,640.00	20,286.00	126,584.64
2F.3	TESTING ROCK BOLTS	EACH	10	1,551.28	15,512.80	10.00	15,512.80
2F.4	DRILLING DRAIN HOLES	LF	9000	8.13	73,170.00	11,235.00	91,340.55
2F.5	SLOTTED PVC PIPE FOR DRAIN HLS	LF	1680	1.68	2,822.40	1,636.00	2,748.48
2F.6	STRIP DRAINS	LF	1800	2.74	4,932.00	4,347.00	11,910.78
2F.7	SHOTCRETE	SY	18750	21.52	403,500.00	21,193.90	456,092.73
2F.8	SHOTCRETE TEST SAMPLES	EACH	380	111.04	42,195.20	347.00	38,530.88
2G.1	SHOTCRETE, FIBER REINFORCED	SY	72500	23.87	1,730,575.00	73,066.10	1,744,087.81
2G.2	ROCK BOLTS (TUNNEL)	LF	108000	4.91	530,280.00	108,876.00	534,581.16
2H.1	SLURRY TRENCH modf= 63	SF	13640	16.43	224,105.20	13,646.70	224,215.28
2I.1	COMPACTED FILL	CY	67000	3.48	233,160.00	77,012.00	268,001.76
2I.2	8-INCH SLOTTED PIPE	LF	700	8.25	5,775.00	712.00	5,874.00
2I.3	8-INCH SOLID PIPE	LF	80	5.12	409.60	80.00	409.60
2I.4	BACKFILL MATERIAL	TON	100	20.20	2,020.00	305.30	6,167.06
2J.1	CLEARING & GRUBBING FOR ROADS	LS	1	59,035.80	59,035.80	1.00	59,035.80
2J.2	ROADWAY EXCAVATION	CY	352000	6.62	2,330,240.00	371,876.00	2,461,819.12
2J.3	EMBANKMENT-IN-PLACE	CY	28400	4.04	114,736.00	28,400.00	114,736.00
2J.4	SPECIAL EXCAVATION	CY	15700	6.32	99,224.00	13,348.00	84,359.36
2J.5	DENSE GRADED AGGREGATE BASE	TON	9600	20.20	193,920.00	9,003.81	181,876.96
2J.6	BIT CONCRETE SURFACE CLASS 1	TON	580	39.34	22,817.20	886.66	34,881.20
2J.7	BIT CONCRETE SURFACE CLASS A	TON	380	40.66	15,450.80	507.14	20,620.31
2J.8	BIT CONCRETE BASE CLASS 1	TON	7340	33.13	243,176.20	7,720.48	255,779.50
2J.9	BIT MATERIAL FOR TACK	TON	3.5	308.72	1,080.52	3.50	1,080.52
2J.10	SLOPED & FLARED BOX 1-0 18-IN	EACH	6	2,351.35	14,108.10	6.00	14,108.10
2J.11	SLOPED & FLARED BOX 1-0 30-IN	EACH	1	3,749.95	3,749.95	1.00	3,749.95
2J.12	CURB BOX INLET, TYPE A	EACH	3	752.95	2,258.85	3.00	2,258.85
2J.13	CURB BOX INLET, TYPE B	EACH	2	3,192.18	6,384.36	2.00	6,384.36
2J.14	JUNCTION BOX, TYPE B	EACH	1	1,882.38	1,882.38	1.00	1,882.38
2J.15	MANHOLE, TYPE A	EACH	1	2,253.30	2,253.30	1.00	2,253.30
2J.16	MANHOLE, TYPE C	EACH	1	4,197.65	4,197.65	0.00	0.00
2J.17	PIPE CULVERT, 15-INCH	LF	140	37.65	5,271.00	149.00	5,609.85
2J.18	PIPE CULVERT, 18-INCH	LF	250	40.66	10,165.00	250.00	10,165.00
2J.19	PIPE CULVERT, 24-INCH	LF	100	52.71	5,271.00	126.00	6,641.46
2J.20	PIPE CULVERT, 30-INCH	LF	72	69.00	4,968.00	72.00	4,968.00
2J.21	PIPE CULVERT, 48-INCH	LF	84	125.00	10,500.00	84.00	10,500.00

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CONTRACTOR: GRASSETTO & INCISA USA (JV)
ADDRESS: P.O. BOX 669 DATE: 25-Jun-93
BAXTER, KY. 40806
CONTRACT NO.: DACW62-89-C-0092 PERIOD COVERED BY THIS ESTIMATE:22 SEP 89 THRU 19 JUN 93

			CONTRACT			TOTAL TO DATE	
ITEM NO.	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	AMOUNT	QUANTITY	AMOUNT
2J.22	PIPE CULVERT, 60-INCH	LF	144	152.65	21,981.60	148.00	22,592.20
2J.23	CONCRETE, CLASS A	CY	28	123.23	3,450.44	27.98	3,447.98
2J.24	STEEL REINFORCEMENT	LB	1650	0.89	1,468.50	1,650.00	1,468.50
2J.25	STEEL "W" BEAM GUARDRAIL mod#= 44	LF	2800	17.43	48,804.00	3,212.50	55,993.88
2J.26	TERMINAL SECTION NO. 1	EACH	1	42.17	42.17	8.00	337.36
2J.27	END TREATMENT, TYPE 2A	EACH	2	430.70	861.40	4.00	1,722.80
2J.28	END TREATMENT, TYPE 3	EACH	2	451.79	903.58	2.00	903.58
2J.29	END TREATMENT, TYPE 4	EACH	1	691.37	691.37	1.00	691.37
2J.30	END TREATMENT, TYPE 7 mod#= 44	EACH	4	677.68	2,710.72	4.00	2,710.72
2J.31	BRIDGE END CONNECTORS, TYPE A	EACH	8	821.43	6,571.44	8.00	6,571.44
2J.32	15-INCH ENTRANCE PIPE	LF	68	27.38	1,861.84	83.00	2,272.54
2J.33	EDGE KEY	LF	90	9.59	863.10	90.00	863.10
2J.34	CONCRETE BARRIER TYPE 12L (TEM mod#= 22	LF	0	41.07	0.00	0.00	0.00
2J.35	PERFORATED PIPE 8-INCH	LF	100	8.25	825.00	100.00	825.00
2J.36	NON-PERFORATED PIPE 8-INCH	LF	20	5.12	102.40	20.00	102.40
2J.37	CONCRETE ENTRANCE PAVEMENT	SY	16	29.03	464.48	32.00	928.96
2J.38	R-OF-WAY MARKERS, RURAL TYPE 1	EACH	50	60.24	3,012.00	50.00	3,012.00
2J.39	P.CEMENT CONCRETE PAVEMENT 8-IN	SY	70	29.03	2,032.10	70.00	2,032.10
2J.40	CHANNEL LINING, CLASS II	TON	190	26.01	4,941.90	246.94	6,422.91
2J.41	STANDARD CURB AND GUTTER	LF	380	12.87	4,890.60	380.00	4,890.60
2J.42	STANDARD INTEGRAL CURB	LF	35	9.04	316.40	35.00	316.40
2J.43	SILT TRAP, TYPE B	EACH	5	281.62	1,408.10	3.00	844.86
2J.44	SILT CHECKS	EACH	25	78.03	1,950.75	13.00	1,014.39
2J.45	MAINTENANCE & CONTROL OF TRAFFI	LS	1	23,000.13	23,000.13	1.00	23,000.13
2K.1	KY. HIGHWAY 38 BRIDGE	LS	1	628,627.23	628,627.23	1.00	628,627.23
2K.2	KY. HIGHWAY 72 BRIDGE	LS	1	************	1,458,453.98	1.00	1,458,453.98
2K.3	STEEL TEST PILES HP 14x73 (BRG	LF	108	45.18	4,879.44	107.81	4,870.86
2K.4	CAST STEEL PILE POINTS	EACH	87	143.07	12,447.09	87.00	12,447.09
2K.5	STEEL PILES 14x73 (BRIDGE)	LF	1650	37.65	62,122.50	1,799.78	67,761.72
2K.6	CYCLOPIAN STONE PROTECTION mod#= 37	TON	0	30.12	0.00	0.00	0.00
2K.7	STR EXCAV (UNCLASS) KY HWY 38 mod#= 39	CY	715	24.86	17,774.90	619.00	15,388.34
2K.8	STR EXCAV (UNCLASS) KY HWY 72 mod#= 37	CY	1720	24.05	41,366.00	1,416.00	34,054.80
2K.9	DRILLED FOUND OVB CAISSONS mod#= 39	LF	150	422.30	63,345.00	138.70	58,573.01
2K.10	DRILLED FOUND ROCK CAISSONS mod#= 39	LF	225	544.36	122,481.00	241.40	131,408.50
2K.11	PROOF TEST HOLES	LF	360	17.25	6,210.00	416.00	7,176.00
2L.1	STEEL SHEET PILING, TYPE PZ 22	LF	160	47.78	7,644.80	176.07	8,412.62
2L.2	STEEL SHEET PILING,TYPE PSZ7.5	LF	1360	56.80	77,248.00	1,625.86	92,348.85
2M.1	STEEL H-PILES (HP 12x74)	LF	1540	37.65	57,981.00	1,265.40	47,642.31
2M.2	PILE POINTS (HP 12x 74)	EACH	46	143.07	6,581.22	46.00	6,581.22
2N.1	TYPE 1 STONE PROTECTION mod#= 37	TON	13410	37.65	504,886.50	14,129.30	531,968.15
2O.1	SEEDING W/ SEED MIX NO. 1	MSF	690	41.07	28,338.30	882.75	36,254.54
2O.2	SEED MIX NO. 1 PLUS CROWN VETCH	MSF	130	54.76	7,118.80	118.58	6,493.44

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JUN 28 '93 11:12 HARLAN (606)573-3457 P.5/12
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CONTRACTOR: GRASSETTO & INCISA USA (JV)
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				CONTRACT		TOTAL TO DATE	
ITEM NO.	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	AMOUNT	QUANTITY	AMOUNT
2O.3	SEED MIX NO.1 PLUS RED CANARY	MSF	40	68.45	2,738.00	0.00	0.00
2O.4	SEED & PROTECT, METHOD 2	MSF	400	54.76	21,904.00	543.60	29,767.54
2O.5	VEGETATIVE MULCH	TON	40	150.60	6,024.00	70.93	10,682.06
2O.6	AGRICULTURAL LIMESTONE	TON	90	32.86	2,957.40	107.68	3,538.36
2O.7	FERTILIZER (10-20-20)	TON	8.5	423.04	3,595.84	10.10	4,272.70
2O.8	FERTILIZER (20-10-10)	TON	2.2	425.78	936.72	0.00	0.00
2O.9	TOPSOIL, 12 INCH THICK	SY	103340	3.01	311,053.40	75,939.88	228,579.04
2O.10	SOD	SY	1000	2.74	2,740.00	519.00	1,422.06
2O.11	PLANTING	LS	1	41,070.93	41,070.93	1.00	41,070.93
2P.1	INSTRUMENTATION	LS	1	45,092.83	45,092.83	1.00	45,092.83
2Q.1	CHAIN-LINK FENCE	LF	1800	60.24	108,432.00	2,096.00	126,263.04
2Q.2	GATES	EACH	4	752.98	3,011.92	4.00	3,011.92
2R.1	GEOTEXTILE mod#= 37	SY	19000	5.51	104,690.00	24,957.17	137,514.01
2R.2	GEOCOMPOSITE	SY	6000	13.23	79,380.00	6,439.35	85,192.60
2R.3	GEOMEMBRANE LINER	SY	15100	11.16	168,516.00	15,896.43	177,404.16
2S.1	UNDERGROUND TANK REMOV & DISP	LS	1	6,317.75	6,317.75	1.00	6,317.75
2T.1	GOVERNMENT OFFICE COMPLEX	LS	1	172,499.55	172,499.55	1.00	172,499.55
2U.1	8-INCH PVC WATERLINE	LF	240	27.59	6,621.60	242.10	6,679.54
2U.2	8-INCH GATE VALVES	EACH	2	750.00	1,500.00	2.00	1,500.00
2U.3	16-INCH STEEL CASING PIPE	LF	190	50.00	9,500.00	190.00	9,500.00
3E.1	TUNNEL BASE SLAB	LF	7740	148.54	1,149,699.60	7,751.00	1,151,333.54
3E.2	NORTH & SOUTHSIDE I-WALL	LS	1	17,853.43	17,853.43	1.00	17,853.43
3E.3	NORTH & SOUTHSIDE T-WALL	LS	1	36,078.70	36,078.70	1.00	36,078.70
3E.4	RAILROAD CLOSURE STRUCTURE	LS	1	52,083.05	52,083.05	1.00	52,083.05
3E.5	PORTAL NOSING	LS	1	############	1,023,469.95	1.00	1,023,469.95
3E.6	CONCRETE HEADWALLS	EACH	2	1,981.35	3,962.70	2.00	3,962.70
5C.1	SWING GATE	LS	1	128,060.70	128,060.70	1.00	128,060.70
	0	0 0	0	0.00	0.00		0.00
	0	0 0	0	0.00	0.00		0.00
	0	0 0	0	0.00	0.00		0.00
	0	0 0	0	0.00	0.00		0.00
	0	0 0	0	0.00	0.00		0.00
	0	0 0	0	0.00	0.00		0.00
	0	0 0	0	0.00	0.00		0.00
	0	0 0	0	0.00	0.00		0.00
	0	0 0	0	0.00	0.00		0.00

TOTAL ORIGINAL CONTRACT AMOUNT w/ORIG BID ITEM MODS ############## $29,530,875.67

ENG Form 93A-E ELECTRONIC VERSION APPROVED BY HQUSACE 15 MARCH 1987.

PAYMENT ESTIMATE - CONTRACT PERFORMANCE(Continuation) SHEET

CONTRACTOR: GRASSETTO & INCISA USA (JV)
ADDRESS: P.O. BOX 669 DATE: 25-Jun-93
BAXTER, KY. 40806
CONTRACT NO.: DACW62-89-C-0092 PERIOD COVERED BY THIS ESTIMATE:22 SEP 89 THRU 19 JUN 93

ITEM NO.	DESCRIPTION	UNIT	CONTRACT QUANTITY	CONTRACT UNIT PRICE	CONTRACT AMOUNT	TOTAL TO DATE QUANTITY	TOTAL TO DATE AMOUNT
APPROVED MODIFICATIONS(ie.NEW ITEMS NOS.)							
----	FUNDS ALLOCATION modif= 1	0	0	$0.00	$0.00		$0.00
----	FUNDS ALLOCATION modif= 2	0	0	$0.00	$0.00		$0.00
----	FUNDS ALLOCATION modif= 3	0	0	$0.00	$0.00		$0.00
----	FUNDS ALLOCATION modif= 4	0	0	$0.00	$0.00		$0.00
2T.2	OVERHAUL & PLACE FILL modif= 5	CY	3146	$2.30	$7,235.80	3,146.00	$7,235.80
2T.3	SEPTIC SYSTEM modif= 5	LS	1	$3,156.00	$3,156.00	1.00	$3,156.00
2T.4	12-INCH CMP modif= 5	LF	90	$21.50	$1,935.00	92.00	$1,978.00
2T.5	#2 & #610 AGGREGRATE modif= 5	TON	1000	$14.53	$14,530.00	1,559.29	$22,656.48
2T.6	BITUMINOUS SURFACE (RE) modif= 5	TON	400	$59.56	$23,824.00	420.60	$25,050.94
2T.7	CHAIN LINK FENCE (RE) modif= 5	LF	794	$15.92	$12,640.48	791.40	$12,599.09
2T.8	FLAG POLE modif= 5	LS	1	$2,350.00	$2,350.00	1.00	$2,350.00
----	TIME EXTENSION - WEATHER 18DAY modif= 6	0	0	$0.00	$0.00		$0.00
2T.9	6-INCH DIAMETER WELL modif= 7	LF	650	$8.90	$5,785.00	765.00	$6,808.50
2T.10	8-INCH CASING modif= 7	LS	1	$2,716.00	$2,716.00	1.00	$2,716.00
2T.11	1-1/4 INCH WATER LINE modif= 7	LF	500	$4.29	$2,145.00	302.00	$1,295.58
2T.12	FURNISH & INSTALL PUMP SYSTEM modif= 7	LS	1	$8,900.00	$8,900.00	1.00	$8,900.00
----	FUNDS ALLOCATION modif= 8	0	0	$0.00	$0.00		$0.00
----	FUNDS ALLOCATION modif= 9	0	0	$0.00	$0.00		$0.00
----	ALTERNATE DISPOSAL AREA GEORGE modif= 10	0	0	$0.00	$0.00		$0.00
----	ADMINISTRATIVE MOD REV SCOPE 5 modif= 11	0	0	$0.00	$0.00		$0.00
2B.2	REMOVE CONTAMINATED MATERIAL modif= 12	CY	250	$92.00	$23,000.00	610.00	$56,120.00
----	FUNDS ALLOCATION modif= 13	0	0	$0.00	$0.00		$0.00
2V.1	8-INCH PVC PIPE modif= 14	LF	936	$112.35	$105,159.60	963.00	$108,193.05
2V.2	ERR	EA	7	$3,815.00	$26,705.00	7.00	$26,705.00
2V.3	CONCRETE ENCASEMENT modif= 14	CY	4.5	$395.00	$1,777.50	5.25	$2,073.75
2V.4	CONCRETE ANCHOR modif= 14	EA	7	$617.00	$4,319.00	7.00	$4,319.00
----	TIME EXTENSION WEATHER 17 DAYS modif= 15	0	0	$0.00	$0.00		$0.00
----	FUNDS ALLOCATION modif= 16	0	0	$0.00	$0.00		$0.00
2D.3	SHOTCRETE BARRIER WALL modif= 17	LS	1	$13,500.00	$13,500.00	1.00	$13,500.00
2B.3	REMOVE CONTAMINATED WATER modif= 18	GAL	20000	$2.10	$42,000.00	19,601.00	$41,162.10
2B.4	LAB TEST modif= 18	EA	6	$365.00	$2,190.00	6.00	$2,190.00
----	FUNDS ALLOCATION modif= 19	0	0	$0.00	$0.00		$0.00
----	TIME EXTENSION WEATHER 4 DAYS modif= 21	0	0	$0.00	$0.00		$0.00
2A.2	ASBESTOS REMOVAL OLD HAR SCH modif= 20	LS	1	$290,745.00	$290,745.00	1.00	$290,745.00
2A.4	DISP other than 3-Cty FILL (b) modif= 20	ls	1	$64,250.00	$64,250.00	1.00	$64,250.00
2T.13	MISCELLANEOUS REVISIONS modif= 23	LS	1	$11,441.00	$11,441.00	1.00	$11,441.00
2A.3	ADDITIONAL CLEARING modif= 22	LS	1	$5,344.00	$5,344.00	1.00	$5,344.00
2M.2	GROUTED CHANNEL LINING modif= 22	LS	1	$7,848.00	$7,848.00	1.00	$7,848.00
2M.46	GOVT BARRIER WALL modif= 22	LS	1	$7,904.00	$7,904.00	1.00	$7,904.00
----	FUNDS ALLOCATION modif= 24	0	0	$0.00	$0.00		$0.00

ENG Form 93A-E ELECTRONIC VERSION APPROVED BY HQUSACE 15 MARCH 1987.

JUN 28 '93 11:13 HARLAN (606)573-3457 P.7/12

PAYMENT ESTIMATE - CONTRACT PERFORMANCE(Continuation) SHEET

CONTRACTOR: GRASSETTO & INCISA USA (JV)
ADDRESS: P.O. BOX 669 DATE: 25-Jun-93
BAXTER, KY. 40806
CONTRACT NO.: DACW62-89-C-0092 PERIOD COVERED BY THIS ESTIMATE:22 SEP 89 THRU 19 JUN 93

			CONTRACT			TOTAL TO DATE	
ITEM NO.	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	AMOUNT	QUANTITY	AMOUNT
----	TIME EXTENSION WEATHER 1 DAY mod#= 26	0	0	$0.00	$0.00		$0.00
2F.9	ANCHOR BOLTS U/S mod#= 25	LF	6040	$11.15	$67,346.00	6,056.00	$67,524.40
2F.10	ANCHOR BOLTS D/S mod#= 25	LF	3265	$9.85	$32,160.25	3,264.00	$32,150.40
2V.5	SEWER LINE TIE IN mod#= 27	LS	1	$36,000.00	$36,000.00	1.00	$36,000.00
----	FUNDS ALLOCATION mod#= 28	0	0	$0.00	$0.00		$0.00
----	DELETE DISPOSAL ALT "A" mod#= 29	LS	1	$0.00	$0.00		$0.00
----	FUNDS ALLOCATION mod#= 30	0	0	$0.00	$0.00		$0.00
----	FUNDS ALLOCATION mod#= 31	0	0	$0.00	$0.00		$0.00
2K.1	ERR	LS	1	$0.00	$0.00		$0.00
----	TIME EXTENSION WEATHER 4 DAYS mod#= 33	0	0	$0.00	$0.00		$0.00
2U.4	HARLAN WATERLINE RELOCATION mod#= 35	LS	1	$9,440.00	$9,440.00	1.00	$9,440.00
----	FUNDS ALLOCATION mod#= 36	0	0	$0.00	$0.00		$0.00
2J.47	SIZE 57 STONE mod#= 37	TON	150	$23.75	$3,562.50	130.55	$3,100.56
2K.12	ERR	CY	120	$108.00	$12,960.00	182.00	$19,656.00
2K.13	CONCRETE OUTSIDE 18 IN LIMIT mod#= 37	CY	65	$106.00	$6,890.00	65.00	$6,890.00
2K.14	DECK DRAINS mod#= 37	LS	1	$9,812.00	$9,812.00	1.00	$9,812.00
2K.15	ERR	TON	1040	$30.12	$31,324.80	961.63	$28,964.30
----	TIME EXTENSION WEATHER 17 DAYS mod#= 38	0	0	$0.00	$0.00		$0.00
2K.16	DRILL FOUND OVB 60 IN CAISSON mod#= 39	LF	75	$830.00	$62,250.00	55.70	$46,231.00
2K.17	DRILL FOUND ROCK 60 IN CAISSON mod#= 39	LF	90	$1,150.00	$103,500.00	106.60	$122,590.00
2K.18	REVISE HWY 38 BRIDGE ABUTMENTS mod#= 39	LS	1	$27,700.00	$27,700.00	1.00	$27,700.00
2J.48	SLIDE REMOVAL HWY 38 mod#= 40	LS	1	$8,200.00	$8,200.00	1.00	$8,200.00
2J.49	TRIM U/S NOSINGS mod#= 40	LS	1	$6,030.00	$6,030.00	1.00	$6,030.00
2J.50	CONCRETE BARRIERS HWY 38 mod#= 40	LS	1	$1,350.00	$1,350.00	1.00	$1,350.00
2D.12	APPALON WITH NETTING mod#= 40	SY	6500	$1.38	$8,970.00	6,938.00	$9,574.44
----	FUNDS ALLOCATION mod#= 41	0	0	$0.00	$0.00		$0.00
----	TIME EXTENSION WEATHER 9 DAYS mod#= 42	0	0	$0.00	$0.00		$0.00
----	FUNDS ALLOCATION mod#= 43	0	0	$0.00	$0.00		$0.00
2E.7	ROCK TRIMMING mod#= 45	LS	1	$33,230.00	$33,230.00	1.00	$33,230.00
2E.8	HAUL ROCK TO D/A mod#= 45	LS	1	$4,570.00	$4,570.00	1.00	$4,570.00
2E.9	SURFACE PREPARATION mod#= 45	LS	1	$12,250.00	$12,250.00	1.00	$12,250.00
2E.10	CONCRETE NOSING mod#= 45	CY	300	$195.00	$58,500.00	625.30	$121,933.50
2E.11	SHOTCRETE (SIDES) mod#= 45	CY	80	$107.00	$8,560.00	149.50	$15,996.50
2E.12	SHOTCRETE (TOP) mod#= 45	CY	20	$130.00	$2,600.00	80.00	$10,400.00
2E.13	12-INCH CORRUGATED METAL PIPE mod#= 46	LS	1	$4,800.00	$4,800.00	1.00	$4,800.00
2J.51	BITUMINOUS SEAL MATERIALS mod#= 47	TON	12	$615.00	$7,380.00	11.65	$7,164.75
2J.52	BITUMINOUS SEAL AGGREGATE mod#= 47	TON	100	$61.50	$6,150.00	227.94	$14,018.31
----	FUNDS ALLOCATION mod#= 48	0	0	$0.00	$0.00		$0.00
----	FUNDS ALLOCATION mod#= 49	0	0	$0.00	$0.00		$0.00
2M.2	CUTOFF/PIPE INTERSECTION mod#= 50	LS	1	$15,000.00	$15,000.00	1.00	$15,000.00
----	WEATHER 2 DAY EXTENSION mod#= 51	0	0	$0.00	$0.00		$0.00
2M.3	ACCESS ROAD RELOCATION mod#= 52	LS	1	$13,465.00	$13,465.00	1.00	$13,465.00

ENG Form 93A-E ELECTRONIC VERSION APPROVED BY HQUSACE 15 MARCH 1987.

P.8/12 JUN 28 '93 11:14 HARLAN (606)573-3457

PAYMENT ESTIMATE - CONTRACT PERFORMANCE(Continuation) SHEET

CONTRACTOR: GRASSETTO & INCISA USA (JV)
ADDRESS: P.O. BOX 669 DATE: 25-Jun-93
BAXTER, KY. 40806
CONTRACT NO.: DACW62-89-C-0092 PERIOD COVERED BY THIS ESTIMATE:22 SEP 89 THRU 19 JUN 93

ITEM NO.	DESCRIPTION	UNIT	QUANTITY	CONTRACT UNIT PRICE	CONTRACT AMOUNT	TOTAL TO DATE QUANTITY	TOTAL TO DATE AMOUNT
2J.53	ABUTMENT DRAINAGE mod#= 53	LS	1	$3,692.00	$3,692.00	1.00	$3,692.00
3E.14	GEOMEMBRANE CONNECTION mod#= 53	LS	1	$582.00	$582.00	1.00	$582.00
2F.11	D\S SLOPE REPAIR mod#= 56	LS	1	$10,634.00	$10,634.00	1.00	$10,634.00
----	TIME WEA OCT - MAR 92 2 DAYS mod#= 57	0	0	$0.00	$0.00		$0.00
2E.15	SURVEY HARLAN ROAD mod#= 58	LS	1	$3,132.00	$3,132.00	1.00	$3,132.00
3D.4	BLASTING CONSULTANT mod#= 58	LS	1	$8,057.00	$8,057.00	1.00	$8,057.00
2T.14	MISC 8 RESIDENT OFFICE mod#= 58	LS	1	$8,261.00	$8,261.00	1.00	$8,261.00
----	FUNDS ALLOCATION mod#= 59	0	0	$0.00	$0.00		$0.00
6K.19	EXCAVATION (BRIDGE) mod#= 60	CY	300	$52.00	$15,600.00	88.48	$4,600.96
2F.12	SHOTCRETE D/S mod#= 60	CY	75	$208.00	$15,600.00	108.00	$22,464.00
2K.13	SHOTCRETE U/S mod#= 60	LS	1	$4,055.00	$4,055.00	1.00	$4,055.00
3D.5	REMOVE BARRIER PIPE mod#= 60	LS	1	$1,370.00	$1,370.00	1.00	$1,370.00
2E.2	EXCAVATION (SPLASH) mod#= 60	LS	1	$10,839.00	$10,839.00	1.00	$10,839.00
2E.3	TYPE 1 STONE (SPLASH) mod#= 60	TN	450	$23.00	$10,350.00	352.87	$8,116.01
2E.4	CONCRETE B (SPLASH) mod#= 60	CY	50	$108.00	$5,400.00	67.00	$7,236.00
----	WEATHER APR-JUN 92 4 DAYS mod#= 61	0	0	$0.00	$0.00		$0.00
----	FUNDS ALLOCATION mod#= 62	0	0	$0.00	$0.00		$0.00
2N.3	STEEL SHEETPILING mod#= 63	LF	3000	$43.70	$131,100.00	2,526.35	$110,401.50
2N.4	PILING EXTRACTION mod#= 63	LF	300	$22.00	$6,600.00	105.00	$2,310.00
2N.5	STANDBY TIME (EQUIP) mod#= 63	HR	40	$40.00	$1,600.00	45.00	$1,800.00
2N.6	KOMATSU 180 mod#= 63	HR	20	$92.00	$1,840.00	22.00	$2,024.00
2N.7	CAT D-4 DOZER mod#= 63	HR	20	$69.00	$1,380.00	15.00	$1,035.00
2N.8	HITACHI 181 mod#= 63	HR	20	$140.00	$2,800.00	68.50	$9,590.00
2N.9	DYNAPAC COMPACTOR mod#= 63	HR	20	$85.00	$1,700.00	0.00	$0.00
2N.10	PC-150 W/TAMPER mod#= 63	HR	20	$105.00	$2,100.00	0.00	$0.00
2N.11	KOMATSU 155A mod#= 63	HR	20	$155.00	$3,100.00	19.50	$3,022.50
2N.12	MOBILIZATION mod#= 63	EA	4	$430.00	$1,720.00	2.00	$860.00
2N.13	ERR	LS	1	$0.00	$0.00		$0.00
2M.3	M-2, CHANNEL LINING mod#= 64	LS	1	$39,200.00	$39,200.00	1.00	$39,200.00
2M.4	TYPE I DITCH, STONE mod#= 64	TN	200	$30.00	$6,000.00	261.33	$7,839.90
2M.5	GROUT, CHANNEL LINING mod#= 64	CY	40	$132.00	$5,280.00	52.00	$6,864.00
2F.14	MISC ITEMS MOD 66 mod#= 66	LS	1	$16,200.00	$16,200.00	1.00	$16,200.00
2F.15	REMOVE SHOTCRETE mod#= 66	CM	30	$207.00	$6,210.00	38.50	$7,969.50
2F.16	PLACE SHOTCRETE mod#= 66	CY	22	$138.00	$3,036.00	15.00	$2,070.00
2F.17	LOAD AND HAUL MATERIAL mod#= 66	HR	10	$271.00	$2,710.00	14.00	$3,794.00
2J.54	HIGHWAY 38 REPAIRS mod#= 66	LS	1	$7,053.00	$7,053.00	1.00	$7,053.00
----	FUNDS ALLOCATION mod#= 65	0	0	$0.00	$0.00		$0.00
----	FUNDS ALLOCATION mod#= 67	0	0	$0.00	$0.00		$0.00
2I.6	REMOVE AND REPLACE COFFERDAM mod#= 68	LS	1	$33,938.00	$33,938.00	1.00	$33,938.00
----	WEATHER DELAY 10 DAYS mod#= 69	0	0	$0.00	$0.00		$0.00
----	FUNDS ALLOCATION mod#= 70	0	0	$0.00	$0.00		$0.00
----	ADMIN REVISE MOD 22 COST CODE mod#= 71	0	0	$0.00	$0.00		$0.00

ORG Form 93A-E ELECTRONIC VERSION APPROVED BY HQUSACE 15 MARCH 1987.

JUN 28 '93 11:14 HARLAN (606)573-3457 P.9/12

RECEIVED 06/28 09:26 1993 AT 615 736 5424 PAGE 9 (PRINTED PAGE 9)

PAYMENT ESTIMATE - CONTRACT PERFORMANCE(Continuation) SHEET

CONTRACTOR: GRASSETTO & INCISA USA (JV)
ADDRESS: P.O. BOX 669
BAXTER, KY. 40806
DATE: 25-Jun-93
CONTRACT NO.: DACW62-89-C-0092
PERIOD COVERED BY THIS ESTIMATE:22 SEP 89 THRU 19 JUN 93

				CONTRACT		TOTAL TO DATE	
ITEM NO.	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	AMOUNT	QUANTITY	AMOUNT
----	FUNDS ALLOCATION mod#= 72	0	0	$0.00	$0.00		$0.00
20.14	MEMBRANE CONNECTION mod#= 73	LS	1	$3,341.00	$3,341.00	1.00	$3,341.00
20.5	RELOCATE WATERLINES mod#= 73	LS	1	$2,890.00	$2,890.00	1.00	$2,890.00
21.7	CLEAN UP TRACTS 614,615 mod#= 73	LS	1	$10,263.00	$10,263.00	1.00	$10,263.00
21.8	EMBANKMENT HAUL mod#= 75	LS	1	$48,216.00	$48,216.00	1.00	$48,216.00
20.6	MISCELLANEOUS EXCAVATION mod#= 76	LS	1	$61,541.00	$61,541.00	1.00	$61,541.00
----	FUNDS ALLOCATION mod#= 74	0	0	$0.00	$0.00		$0.00

ENG Form 93A-E ELECTRONIC VERSION APPROVED BY HQUSACE 15 MARCH 1987.

JUN 28 '93 11:15 HARLAN (606)573-3457 P.18/12

4. Foundation Exploration and Testing.

4.1 Investigations Prior to Construction. During the period from 1984 through early 1989, numerous investigations were conducted in the areas of the portals, tunnels, bridge abutments, roadways, and diversion structure.

Soils testing included USCS classification, Standard Penetration Testing, determination of moisture content, Atterberg limits, and gradations. Rock testing included determination of unconfined compressive strength, elastic moduli, seismic velocity, point load index, Poisson's ratio, direct shear strength, and unit weight. Rock properties and test data graphs and tables, taken from Feature Design Memorandum No. 3, are presented in Section 5.3, "Engineering Characteristics of Foundation Materials".

The locations of preconstruction borings are shown on PLATES B-2, C-2, and D-2. All boring logs and test data are included in the Harlan Diversion Project Feature Design Memorandum No. 3 and in the construction Specifications for the Harlan Diversion Project-Appendices A and B.

4.2 Investigations During Construction. Investigations during construction consisted of exploratory air-track and jack-hammer drilling, core drilling, and trenching. Testing included determination of unconfined compressive strength, slake durability, and gradations.

4.2.1 Downstream Portal Investigations.

4.2.1.1 Drilling and Trenching. On 7 November 1989 seven exploratory air-track holes were drilled to locate top of rock in the downstream portal area. On 13 November five more air-track holes were drilled to determine top of rock along Kentucky Highway 72 near future bridge abutment number 2. These holes indicated a steeply dipping top of rock surface, on approximately the same slope as the original ground surface. Elevations at which rock was encountered did not differ significantly from information presented in the contract drawings.

On 16 January 1990 three backhoe trenches were dug to determine the depth to rock along the planned ten-feet-wide bench above the tunnels. The actual rock surface was found to be 7½ to 9 feet lower than the estimated rock line. On 23 January 1990 five nearly horizontal air-track holes were drilled to determine distance to unweathered rock on the 1V:1H slope above the ten-feet-wide bench. Harder rock was found 9 to 13 feet behind the existing slope. Because rock at the design bench level was lower than estimated and because of slides in the overburden and weathered siltstone 1V:1H slopes, adjustments were made to the backslope. These changes are discussed further in Section 6 of this report.

4.2.1.2 Testing. In September 1990 samples of rock blasted from the downstream portal area were tested for slake durability. The samples were taken by the contractor and tested by C.V.E. Testing of Harlan. All material exceeded the minimum SDI of 95% required for use in the Kentucky Highway 72 roadway embankment.

Slake Durability Index (SDI)

Tunnel	Station	Elev.	Rock Type	SDI
1	D/S Portal	1175	Siltstone	98.9%
2	D/S Portal	1175	Siltstone	97.9%
3	D/S Portal	1175	Siltstone	98.8%

All samples were described as dark gray, massive, sandy shale, elsewhere described as siltstone, and tested with Kentucky method #64-513-79 (ASTM D 4644-87). This test method covers the determination of the durability index of a shale or other similar rock after two drying and wetting cycles with abrasion. Slake durability index is defined as the percentage of dry mass retained of a collection of shale pieces on a No. 10 sieve after two cycles of oven drying and 10 minutes of soaking in water with a standard tumbling and abrasion action. Despite the high test results, siltstone roadheader cuttings used as fill on the diversion embankment broke down significantly during the placement, leveling, and compaction processes. Wet material pumped under equipment load and it became necessary to control the moisture content in constructing the embankment.

4.2.2 Upstream Portal Investigations. Seven air-track holes were drilled to determine the elevation of hard rock across the top of the vertical portal backslope from baseline A to baseline C. See Plate C-8 for baseline locations. Harder rock was found to be about ten feet below the design bench elevation. Based on drilling results the upstream portal slopes were changed as described in Section 7.1.

4.2.3 Highway 72 Bridge Investigations.

4.2.3.1 Drilling. Three five-feet-deep jackhammer holes were drilled in each pier foundation to determine it's suitability, as required by Kentucky Standard Specifications for Road and Bridge Construction and the Division of Construction Guidance Manual. All nine holes indicated moderately hard siltstone, with no voids below foundation level.

4.2.3.2 Testing. From December 1990 through February 1991, more siltstone samples from the Highway 72 bridge pier foundations were tested to determine slake durability. Material from this area was used as backfill around the bridge abutments. Test results are tabulated on the next page.

Slake Durability Index

Pier No.	Location	Elev.	Rock Type	SDI
1	20 ft. from U/S end	1150	Siltstone	96.6%
1	14 ft. from D/S end	1148	Siltstone	96.3%
2	Not Recorded	1149	Siltstone	97.9%
3	Not Recorded	1148	Siltstone	97.2%

4.2.4 Highway 38 Bridge Investigations.

4.2.4.1 Drilling. Each of the Highway 38 bridge abutments is supported by eight caissons. Before the caisson holes were augered, proof test NX core holes were drilled to a level five feet below the proposed bottom of each caisson. Bedrock was lower than expected in some areas, requiring modification to caisson design. Where revisions deepened and relocated caissons, jackhammer proof test holes were drilled five feet below the bottom of the completed caisson hole. The Highway 38 bridge foundation is discussed in detail in Section 11 of this report. Logs of drill holes are included in Appendix H, PLATES H-3 and H-4.

4.2.4.2 Testing. In documenting foundation conditions the Corps of Engineers tested cores from the proof test holes to determine unconfined compressive strength. Test results, in pounds per square inch (PSI), are recorded below.

Caisson No.	Sample Elev.	Rock Type	PSI
A2-1	1197.7	Sdy siltstone	12,891
A2-2	1172.0	Sdy siltstone	8,435
A2-3	1182.0	Siltstone	6,605
A2-4	1189.5	Siltstone	4,647
A2-4	1179.5	Sdy siltstone	10,822
A2-4	1174.5	Sdy siltstone	9,549
A1-7	1172.0	Siltstone	4,535
A2-5	1175.0	Siltstone	7,162
A1-5	1160.5	Sdy siltstone	12,700

4.2.5 Tunnel Investigations. To provide documentation of tunneling conditions, rock cores from the tunnels were tested to determine unconfined compressive strength. The samples were cored by the contractor and tested by both the contractor and the Corps of Engineers project laboratory. Test results in pounds per square inch (PSI) are tabulated below.

Unconfined Compressive Strength Test Results

Tunnel	Station	Rock Type	PSI	Date Tested
2	10+71	Siltstone	2,200*	9- -90
2	10+71	Siltstone	3,750	9- -90
2	10+71	Siltstone	6,262	9- -90
2	10+71	Siltstone	5,375	9- -90

Unconfined Compressive Strength Test Results

Tunnel	Station	Rock Type	PSI	Date Tested
2	10+71	Siltstone	2,812	9- -90
1	19+80	Sandstone	18,125	1-09-91
1	19+80	Sandstone	13,875	1-09-91
1	19+80	Sandstone	+17,800**	1-10-91
1	20+86	Siltstone	3,062	1-09-91
1	20+86	Siltstone	6,062	1-09-91
1	20+86	Sdy siltstone	10,350	1-10-91
2	13+42	Siltstone	5,500	1-09-91
2	13+42	Siltstone	5,750	1-09-91
2	13+42	Siltstone	4,725	1-10-91
2	18+86	Siltstone	4,500	4-12-91
3	14+10	Sdy siltstone	10,250	4-12-91
3	14+10	Sdy siltstone	9,000	4-12-91
2	19+85	Siy Sandstone	11,250	4-30-91
3	17+47	Siltstone	2,500	5-01-91
3	17+47	Siltstone	3,000	5-01-91
3	19+80	Sdy siltstone	10,750	5-20-91
3	20+70	Sdy siltstone	8,750	5-29-91
3	22+30	Sdy siltstone	8,500	5-29-91

* Test results believed to be inaccurate because of a bad cap.
** Sample not taken to failure.

The number of cores taken in different materials may be biased toward the higher strength sandy material which occurs in widely spaced bands and beds ranging from less than 0.1 foot to 2.4 feet thick. Material excavated from the tunnels is about 92 per cent siltstone with a compressive strength ranging from about 4,000 to 6,000 PSI. The actual extent of the different materials is shown on tunnel geology maps in Appendix D, Plates D-12 through D-169.

4.2.6 Slurry Trench Investigations.

4.2.6.1 Backfill Borrow Site. In August and September 1991, several backhoe pits were dug in the alluvium upstream of the embankment and adjacent to Clover Fork to locate the best borrow site for slurry trench backfill material. Gradation test results indicated that, although on the fine side of the specification requirement, suitable backfill material was available from the upper four to six feet of the alluvium. Details of slurry trench construction are presented in Section 9.2 of this report. A test pit location plan and gradation results are included in Appendix E, PLATES E-8 through E-10.

4.2.6.2 Right Abutment of Diversion Embankment. In June 1992, the contractor drilled four air-track holes to determine depth to bedrock in the right abutment area. Indications were that the top of rock surface was lower than the estimated top of rock line. A Corps of Engineers drill crew drilled three additional SPT/core holes which confirmed

the preliminary findings. This led to a modification extending the foundation seepage cutoff farther into the right abutment with the addition of a sheet pile wall section. See Section 9.?, "Slurry Trench".

5. Geology

5.1 Regional Geology. The Cumberland River basin upstream of Pineville, Kentucky comprises the northwestern two-thirds of the Cumberland Mountains region, a subdivision of the Cumberland Plateau physiographic province. The region is about 25 miles wide by 125 miles long and lies entirely within the Pine Mountain Overthrust. It is bounded on the northwest by Pine Mountain and on the southeast by Cumberland Mountain, two asymmetric ridges with general crest elevations of 2,500 and 2,800 feet above mean sea level respectively. The topography of the area is in early maturity typified by rugged mountainous terrain dissected by a well developed drainage system which varies from rectangular to dendritic in form. The highest point in Kentucky, The Double on Black Mountain (Elev. 4,150), is located in the headwaters of the Cumberland River. The valleys are steep sided and narrow.

5.2 Site Geology.

5.2.1 Physiography. The tunnels were excavated through Ivy Hill, a southwesterly trending spur which extends from the southwest end of Black Mountain. Generally, elevations range between 1,152 feet above mean sea level (stream bed elevation at the downstream portal) to over 3,300 feet at the closest peak on Black Mountain. The maximum elevation above the tunnels is 1524 feet. The average depth of cover over the crown of the tunnels is approximately 218 feet with the maximum being 324 feet. The hillside slopes are variable but generally are very steep, varying between 1V:1H to 1V:3H. The Cawood Sandstone member forms prominent cliffs in many areas around the project site. The floodplains of the Cumberland River and its major tributaries are irregular in width due to migration of channels. This migration produces an alternating wide and narrow floodplain. The banks of the river are steep, sloping about 1V:3H.

5.2.2 Description of Overburden. Overburden soils and soil-like materials in the project area are generally one of four types: residuum, colluvium, alluvium, or artificial fill. Residuum, or residual soil, is decomposed bedrock characterized by its clayey and sandy clay nature and relict bedding texture. Colluvium, found on hill slopes and at the base of slopes, is generally loose accumulations of sandy soils containing boulders, cobbles, and rock fragments which have fallen from outcroppings of the overlying Cawood Sandstone. Alluvial soils are found at the lower elevations of the project where they have been deposited by the waters of Clover Fork. Alluvial materials range from silts to gravels, and may be mixed with colluvium and artificial fill. Artificial fill is

found throughout the project area primarily in association with railroad, highway, or dwelling construction. The upstream area, most notably the H-2 disposal site and the diversion embankment site, contained large amounts of trash, scrap metal, and other waste materials classified as artificial fill.

5.2.3 Bedrock Stratigraphy. The Harlan Diversion project is located entirely within the outcrop area of the Hance formation. The material immediately below the tunnels is part of the upper Hance coal zone. It is marked in the tunnel exploration at about elevation 1140 in borings C-200, C-201, and C-207. Above this is 160 to 180 feet of slightly micaceous, moderately hard gray siltstone through which the tunnels were driven. This material varies in character across the site being more shaly in some areas and more massive in others. This has led to variations in the description of this material between the two extremes of siltstone and shale. X-ray analysis and the appearance of most of the core tends to support a classification as siltstone however the bedding characteristics in some locations suggest a shale. It is generally referred to as a siltstone since this seems to represent the majority of the material. Within the tunnels, bedding is generally massive except for thin to thick (0.1 foot to 2.4 feet thick) beds of hard, light gray, very fine grained, quartzose sandstone and sandy siltstone. These were confined mainly to the middle one-third of the tunnels. They were all hard and continuous to discontinuous. At most they constitute about 8% of the tunnel excavation.

The upper contact of the siltstone facies is transitional with the Cawood Sandstone member becoming interbedded and commonly cross-bedded, variably silty, micaceous, and carbonaceous, moderately hard to hard, fine to medium grained, well cemented, light gray to tan with occasional carbonaceous or shaly zones. The sandstone forms low cliffs on the flanks of Ivy Hill about 140 feet above the crown of the tunnels. These cliffs are the source of the abundant large blocks of sandstone which are found in the colluvium at the base of the slopes.

5.2.4 Bedrock Structure. Bedding is nearly horizontal, with dips ranging between 0 and 7 degrees to the southwest. Bedding thickness varies across the site being more shaly in some areas and more massive in others. Within the tunnels, bedding is generally massive except for thin to thick beds of hard, light gray, very fine grained, quartzose sandstone and sandy siltstone. These were confined mainly to the middle one-third of the tunnels.

Joints spacing ranges from very closely spaced to extremely widely spaced and are usually extremely widely spaced. Most joints are generally planar to slightly curved, of moderate to high continuity, tight, clean, slightly rough to smooth, not healed, and dry. Joints located near the original ground surface are sometimes stained or contain a moderately thin filling of silty clay, and show water seepage. Zones of curved

joints, up to 2½ feet thick, occur in the portal areas and along the Hwy 38 road cut. These zones are composed of very closely spaced, parallel, tight joints with a moderately thin, very soft, residual silty-clay filling. The joint surfaces are smooth, not healed, and commonly show water seepage. The strike of these features is often nearly parallel to the adjacent river channel and the dip is high angle, curved, and irregular. They are difficult to project downward because they often step riverward along bedding planes.

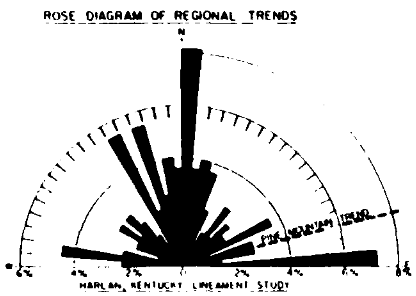
Occurrance of prominent joints in the tunnels is confined to an area within about 100 feet of either portal, relatively near the original ground surface. These are typically of moderate continuity, tight to wide open, smooth to slightly rough, not healed, and stained. There was no evidence of faulting in any of the tunnel or portal excavations. Graphical representation of discontinuity data is included in Section 5.3.

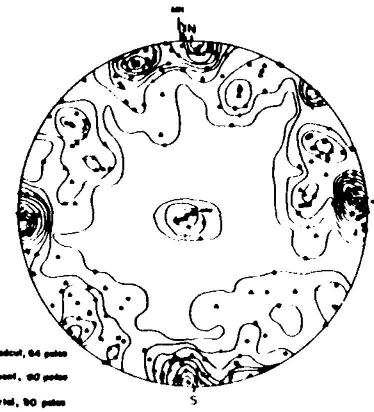
5.2.5 Bedrock Weathering. At the overburden/bedrock contact and along near surface discontinuities the bedrock is highly weathered to decomposed with the siltstone reduced to a soft soil with relict rock texture (residuum). Depth of weathering varies but is usually limited to less than ten feet below top of rock.

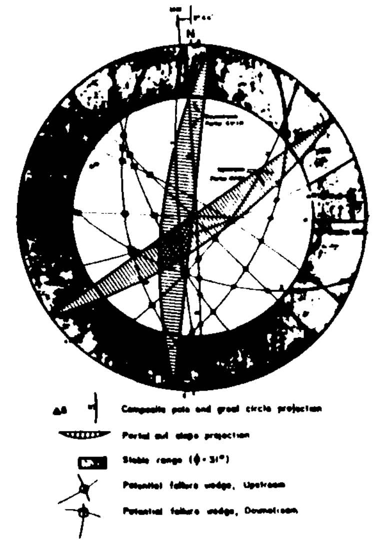
5.2.6 Groundwater. Within the Harlan project area groundwater occurs in both the alluvial soils and in the bedrock. The groundwater in the alluvium is at or slightly above the adjacent river level. The permeability of the bedrock is low and the occurrance of groundwater is more dependent upon fracturing of the rock. For this reason well yields are extremely variable.

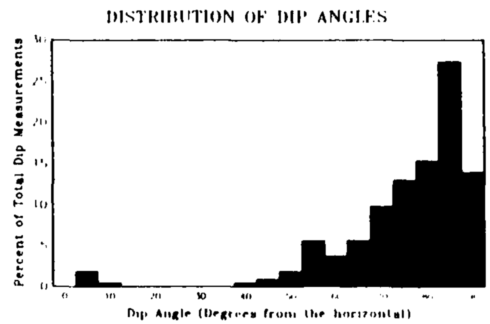
Observation well C-204 located on Ivy Hill near tunnel 4 was monitored throughout the tunnel construction contract. Water levels in this well remained stable throughout construction. A graph of water levels is included in Appendix I, PLATE I-23.

5.3 Engineering Characteristics Foundation Materials. Engineering characteristics of the foundation rock are presented on pages 20 through 24. These graphs and tables were taken from Feature Design Memorandum No. 3. Complete data from testing conducted during the project design phase are presented in the Harlan Diversion Project Feature Design Memorandum No. 3, Engineering Features and in the construction specifications for the Harlan Diversion Project, Appendices A and B. Design of the diversion tunnels and characteristics of foundation materials was the subject of an article by Marvin Simmons and John Stanton, published in the Bulletin of the Association of Engineering Geologists, No. 1, 1991.

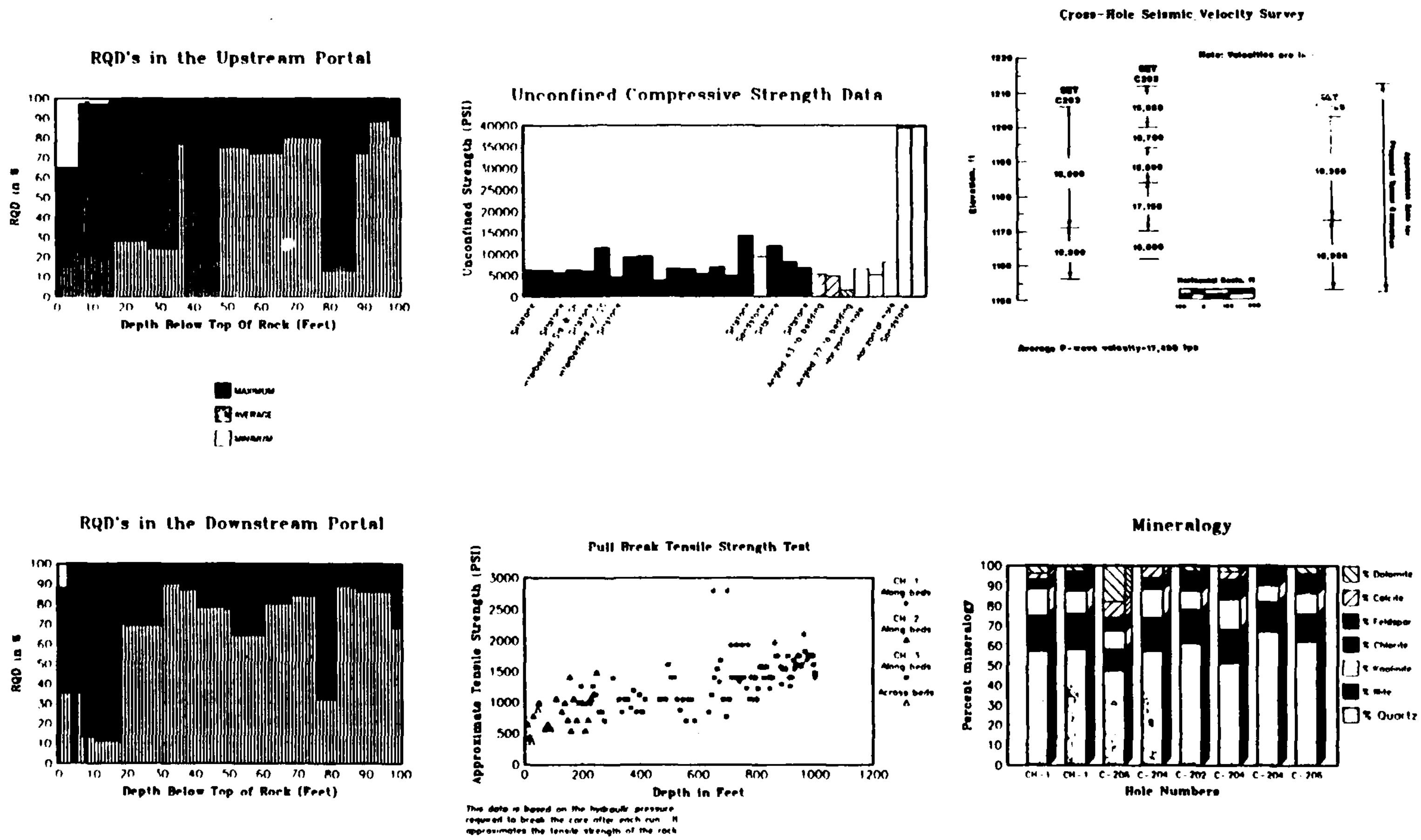




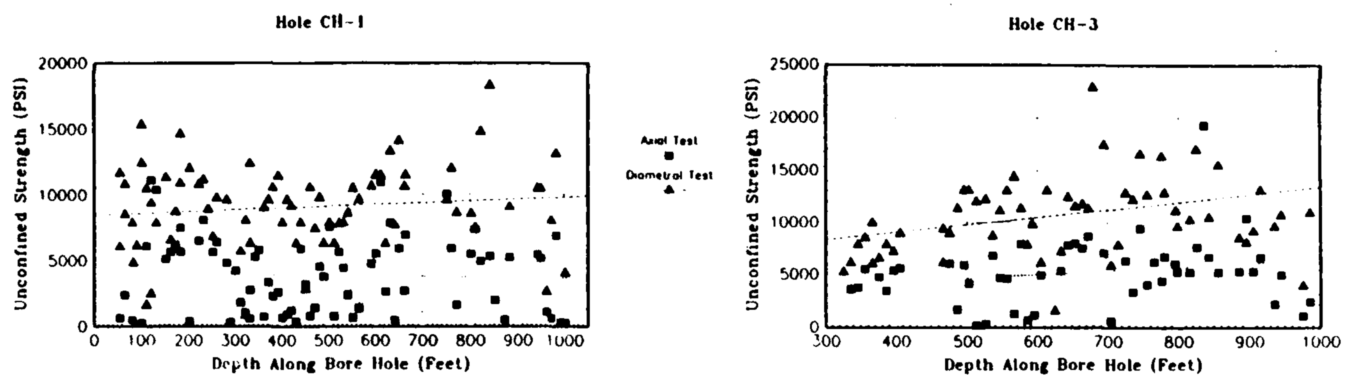




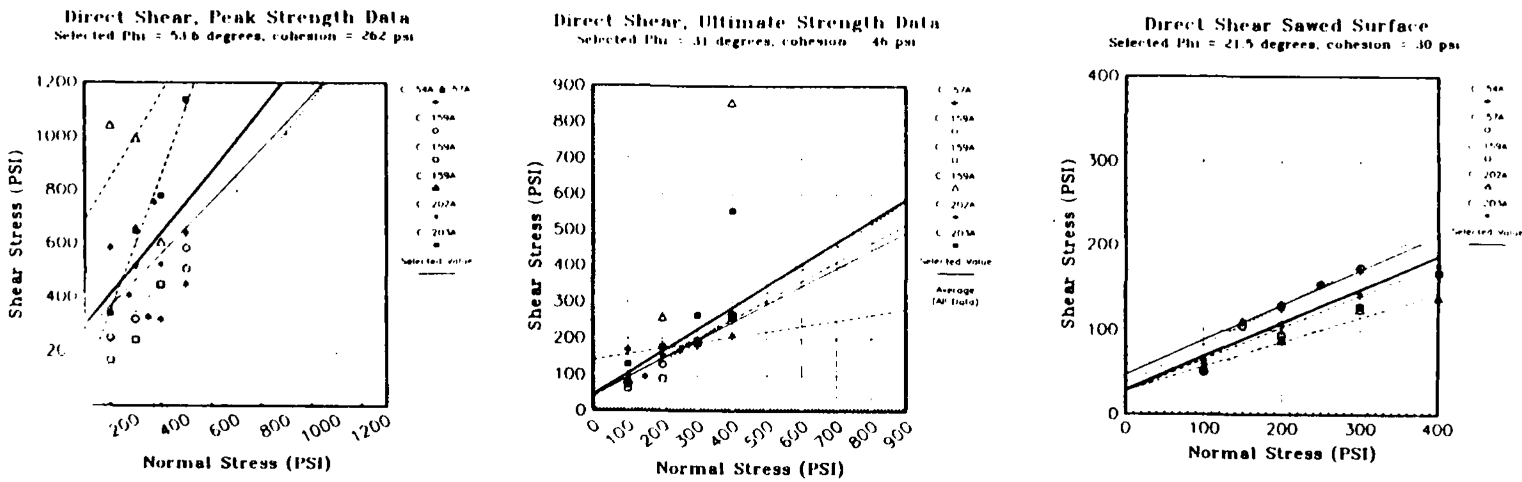
Results of discontinuity studies.



Rock mass properties and test data.



Point load test data from horizontal borings, performed with an SBEL model PLT-10. The lines shown are a best fit linear regression analysis. Unconfined strength is based on the point load index multiplied by 24.



Direct shear strength test data.

Rock properties and triaxial strength test data.

Hole Number	Material	Sample Elevation	Unconfined Compressive Strength	Modulus of Elasticity x 10^6 psi	Poisson's Ratio	Triaxial Compressive Strength ϕ (degrees)	Triaxial Compressive Strength C psi	Tensile Strength psi	Orientation of Loading to Bedding (degrees)	Unit weight lb/cu ft
C-54A	Siltstone	1,424.9	6,250	0.710	0.250				90	168.7
C-54A	Siltstone	1,424.1	5,620	0.677	0.259				90	167.3
C-54A	Shaly Sandstone	1,389.3	8,620	1.127	0.183				90	163.3
C-54A	Shaly Sandstone	1,386.2	12,580	3.150	0.146				90	163.2
C-54A	Sandstone	1,384.9	18,070	5.191	0.146				90	159.5
C-57	Siltstone	1,291.5	6,290	0.772	0.241				90	167.3
C-57	Shale & Siltstone	1,290.6	6,290	1.007	0.209				90	167.3
C-200	Siltstone	1,200.3	4,950						42	
C-200	Siltstone	1,199.0	5,200						42	
C-200	Siltstone	1,187.4				39	190		42	
C-200	Siltstone	1,177.5				37	400		42	
C-202	Siltstone	1,195.1						1,060	90	
C-202	Siltstone	1,194.7	4,600						90	
C-202	Siltstone	1,187.4	9,280						90	
C-202	Siltstone	1,182.5	9,430	6.410					90	
C-203	Siltstone	1,180.2	8,120						90	
C-204	Siltstone	1,209.8						1,750	90	
C-204	Siltstone	1,179.7	9,500						90	
C-204	Siltstone	1,168.2	14,250	6.529	0.186				90	
C-204	Siltstone	1,156.9	3,750						90	
C-206	Siltstone	1,165.7	6,520						90	
C-206	Siltstone	1,165.3	6,520						90	
C-206	Siltstone	1,153.7	11,830	4.511	0.255				90	
C-285	Siltstone	1,192.2				38	1,800		90	
OC-293	Siltstone	1,164.4	6,680						90	
C-296	Siltstone	1,208.6	1,600						77	
CH-1	Siltstone	1,208.9	5,260						0	
CH-1	Siltstone	1,205.8						530	0	
CH-1	Siltstone	1,205.7	6,560						0	
CH-1	Siltstone	1,198.9	8,130						0	
CH-1	Siltstone	1,198.8						530	0	
CH-3	Siltstone	1,168.7				35	1,000		0	

Summary of direct shear test data.

Hole Number	Material	Sample Elevation	Intact Rock Peak ϕ (degrees)	Intact Rock Peak C psi	Intact Rock Ultimate ϕ (degrees)	Intact Rock Ultimate C psi	Bedding Plane Ultimate ϕ (degrees)	Bedding Plane Ultimate C psi	Sawed Surface Ultimate ϕ (degrees)	Sawed Surface Ultimate C psi
C-54A	Siltstone	1,424.5	58	165						
C-54A	Shaly Sandstone	1,383.9					30	5		
C-55A	Shaly Sandstone	1,383.2	69	197	29	27				
C-55A	Shaly Sandstone	1,383.0					35	22		
C-55A	Shaly Sandstone	1,373.3							31	4
C-55A	Shaly Sandstone	1,373.1							26	12
C-57	Siltstone & Shale	1,282.5	65	190	26	45				
C-57	Siltstone	1,281.1					26	30		
C-57	Siltstone	1,279.4					28	17		
C-159A	Siltstone	1,197.2	45	37	29	2				
C-159A	Siltstone	1,184.3	53	40	30	16				
C-159A	Siltstone	1,178.6							21	12
C-159A	Siltstone	1,179.5	50	35	33	0				
C-202A	Siltstone	1,179.4							19	18
C-202A	Siltstone	1,166.4	36	36	22	3				
C-202A	Siltstone	1,160.6			17	92				
C-202A	Siltstone	1,156.4	23	109	14	31				
C-203A	Siltstone	1,341.3	72	35	32	0				
C-203A	Siltstone	1,203.0	40	115	26	35				
C-203A	Siltstone	1,194.2	69	80						

6. Downstream Portals

6.1 Excavation Grades - Design and As-Built.

6.1.1 Overburden. Overburden slopes were designed to be 1V:1H along the left side slope and above the tunnel portals, and 1V:2H along the right side slope, as shown on the general plan of the downstream portal, PLATE B-1. During construction, slides developed on the 1V:1H overburden slopes, some of them extending back to joint faces in highly weathered rock. Treatment consisted of laying back the slope to 1V:1½H in overburden, or to the joint faces which had been exposed in rock. As a result, some of the overburden slopes were flatter or set back farther into the hillside than originally planned. An increase in excavation quantities resulted. Design and as-built cross-sections are included in Appendix B.

6.1.2 Rock. All finished rock slopes were presplit. The specifications allowed a one foot offset between lifts and limited lift depth to 30 feet. Approval was given to the contractor's request to offset slopes three feet between lifts to accommodate drilling equipment, as shown on PLATE B-8.

A ten-feet-wide bench was to be constructed at the top of rock. To establish the bench, a 2V:1H slope was presplit from top of rock down to bench level. Below this bench, rock slopes were designed to be 4V:1H and vertical. Because of low rock at the

bench level and continuing development of slides in the 1V:1H slopes, the bench at top of rock was set back 15 feet into the hillside. A new 1V:1H backslope was laid out. Rock was encountered at approximately elevation 1290. A 2V:1H presplit slope was developed from approximately 1290 to 1270. This allowed final slopes to be constructed in harder, less weathered rock. An extra bench was created and the design bench was lowered and widened.

Overbreakage resulted in areas where joints occurred behind the presplit surfaces. The rock was often too fractured to bolt effectively. In such areas loose blocks were removed and joint faces, rather than presplit faces, form the finished slope.

Below elevation 1230, blasting caused the rock to shift along smooth, nearly horizontal bedding planes and high angle joints which crossed the outside corners. Displaced rock was either pinned with additional rock bolts, or removed. Because of this, in some areas the final excavated surfaces were below and behind design lines.

PLATE B-10 illustrates plan and as-built slope configurations as well as overburden/soft-rock/hard-rock contacts as determined from contractors survey data, exploratory pits, and drill holes.

6.2 Dewatering Provisions. Groundwater entering the downstream portal excavation was limited to small seeps occurring primarily at the overburden/rock contact and along bedding planes and joints. The total amount of groundwater seepage was negligible compared to surface runoff.

Control of surface water runoff was necessary to prevent flooding of the work area during periods of rainfall. An intermittent stream entered the area above the tunnel 1 portal. A shotcrete dam was constructed to divert the stream into an 18-inch diameter corrugated polyethylene pipe which carried it down the slope and away from the work area. Water which collected in the work area was processed through a water treatment plant to remove suspended solids, and then pumped into Clover Fork.

6.3 Overburden Excavation.

6.3.1 Dates. Surveyors began layout at the downstream portal area during the last week of September 1989. Overburden excavation began in November 1989 and continued in conjunction with rock excavation until July 1990.

6.3.2 Methods and Equipment. Excavation began at the top of the portal area. Two D-8 Caterpillar dozers and a Komatsu PC150LC backhoe cut the 1V:1H slope and moved the material to an existing bench at approximately elevation 1215. Large sandstone boulders which were uncovered during overburden removal were blasted so they could be loaded and hauled to

disposal. A John Deere 844 and a Fiat Allis 745H rubber-tired endloader loaded material into 16 cubic yard capacity highway dump trucks which transported it to disposal area L-11 by way of Route 72 and US 119.

6.3.3 Construction Summary, Problems, and Treatment. The general treatment of the portal slopes included installation of rock anchors on an 8 by 8 feet pattern, strip drains, and a four-inches-thick, welded-wire-fabric reinforced, shotcrete covering.

Occasionally, shotcreting of the 1V:1H backslope was delayed beyond contract specified time limits, for two reasons, (1) slides required repositioning of finish slopes and (2) design slopes were dependent upon an estimated top of rock line. When rock was encountered lower than anticipated, benches and backslopes had to be lowered or set back into the hillside. Both of these conditions were unpredictable and required that shotcrete application be delayed so that benches and slopes could be adjusted as the excavation progressed. For these reasons overburden slopes were not shotcreted.

In December 1989, excavation of the 1V:1H backslope began along the left portal slope between stations 7+00 and 9+80. A slide began developing along the top of this 1V:1H slope, between station 8+25 and 8+75 on 15 December, 1989. Tension cracks developed 15 feet upslope from the top at the 1V:1H cut, accompanied by bulging and cracking in the overburden and weathered rock portion of the slope. The material was removed and the slope stabilized by laying it back to 1V:1½H. The slope was warped into the steeper 1V:1H slopes on either side. Removing the slide and laying back the slope moved the top of the cut uphill and outside project limits, requiring the acquisition of additional property.

During January 1990, slides continued to develop on 1V:1H backslopes. Two slides located along the left side slope from station 8+10 to 8+60 and from 9+30 to 9+75 occurred along joint planes which trend N15°W, 60° SW; nearly parallel to the cut slope. Seepage along the overburden/siltstone contact and along the joint planes saturated the overburden and contributed to slope failure. Treatment consisted of removing slide material back to the joint face using a D-8 dozer and backhoe.

Slides also developed along the 1V:1H backslope above tunnels 2 and 3. Cracks appeared in the ground surface above the top of the cut- slope, accompanied by cracking and outward movement in the weathered siltstone along a nearly horizontal bedding plane. After heavy rains on 10 and 11 February 1990, an overburden slide occurred from station 7+50 to 8+00 on the left side slope. Saturated soil continued to slide along a joint face which intersected the cut slope. Cracking in the overburden extended 13 feet upslope of the clearing line. A backhoe was used to remove slide material back to the joint face.

Downstream Portals.

6.3.4 Disposition of Materials. Most of the overburden excavated from the downstream portal area was hauled to disposal area L-11. In December 1989, a small amount was used as fill at the Corps of Engineers office site.

6.4 Rock Excavation.

6.4.1 Dates. Rock excavation began at the downstream portal in January 1990 and was completed on 14 September 1990.

6.4.2 Methods and Equipment. Blasting began at the top of rock, about elevation 1290 at its highest point, and continued to the finished grade near elevation 1155. Ingersoll Rand ECM 350 air-track drills with 750 CFM air compressors were used to drill blast holes. A Gardner-Denver RDC 16 rotary drill was used briefly, during May 1990, to drill 5⅛-inch diameter blast holes for ten production blasts. A Caterpillar D-8 dozer pushed material to a John Deere 844 and a Fiat Allis 745H endloader for loading into trucks which transported it to the disposal area.

6.4.3 Blasting. All finished rock slope surfaces were presplit. Presplit drilling and blasting began in February 1990 on the 2V:1H slope from top of rock down to bench level, approximately elevation 1290 to 1270. During March 1990, blasting continued with development of the 4V:1H presplit slope and production blasting from approximately elevation 1270 to 1245. In April blasting continued on the right side slope along Baseline "A", along the backslope above the tunnel portals, and along the outside corners of tunnels 1 and 2. Details of initial presplit (PS) and production (Prod) blasting are shown on the next page.

Type	Dia.	Spacing	Depth	Stem	Powder	lbs/delay
PS	2½-3"	36"	15-30'	2-4'	Detagel, Iresplit 200 grain Primacord	-----
Prod	4"	5x5, 6x6, 7x7	8-15'	6-7'	ANFO, Iremite	40-65

Presplit blasts were detonated with electric blasting caps. Production blasts were detonated with the Nonel system. The first presplit shot across the face of tunnel 1 was loaded with 200-grain detonating cord only and failed to produce good breakage. The holes were cleaned out and reloaded with detonating cord and Detagel which produced satisfactory results.

Excavation continued on the downstream portals to approximately elevation 1200 during May 1990. This included presplitting adjacent to tunnels 1, 3, and 4. Production blasting continued in front of tunnel 2. Experimentation with different materials and techniques were conducted in an effort to reduce blast damage to the outside corners. Additional vertical rock bolts and pattern rock bolts were installed before adjacent blasts

were fired. Despite the precautions that were taken, some damage did occur and this resulted in final excavated surfaces that were below and behind design lines.

Presplit (one 30-feet lift) and production blasting (two 15-feet lifts) continued from elevation 1230 to 1200 in front of tunnels 3 and 4. The left side slope, along baseline C from station 11+00 to 11+66, was presplit in one lift from elevation 1215 to 1186. Details of typical blasts are shown below.

Type	Dia.	Spacing	Depth	Stem	Powder
PS	2½"	36-18"	30'	1½-4'	Primacord (200 gr), Detagel, Unigel, Iresplit. EB Caps.
Prod	3-5"	6x6,9x9'	15'	3-8'	ANFO, Iregel, Iremite primers Nonel initiation.

Experimentation with different presplit materials, hole spacing, and deck loading was done in an effort to reduce blast damage to the outside corners of the downstream portals. To reinforce the corners, ten and twenty feet long vertical rock bolts were installed on the outside corners of tunnels 1 and 3 prior to blasting. Pattern rock bolts were installed in vertical faces before adjacent blasting. Installation of anchor bars, welded wire fabric, and shotcrete continued within the time restraints set forth in the specifications. Despite the precautions damage occurred as rock shifted along smooth, nearly horizontal bedding planes and high angle joints which cross the outside corners. Displaced rock was secured with additional rock bolts, or removed. Blast damage to shotcrete also became a problem. A production blast in front of tunnel 3 from elevation 1215 to 1200 resulted in shifting of the tunnel 2 corner along a joint and bedding planes and damaged shotcrete on the face of tunnel 2.

The Contractor employed Dr. James Mahar, a rock mechanics consultant, to evaluate conditions at the downstream portal. Dr. Mahar presented his findings and recommendations at a meeting held at the Pineville Area Office on 1 June 1990. The recommendations included the installation of 40-feet long, vertical, stressed anchors on two-feet centers around the corners and two feet inside the presplit lines. Extra length rock bolts installed normal to joints which cut across the corners were also recommended. It was suggested that the blasting plan be re-evaluated and modified if necessary.

Presplitting the remaining 45 feet in one single lift was discussed, this being a way of preserving more of the rock corner by eliminating a horizontal offset which would be required if two separate presplit shots were made.

A modified version of Dr. Mahar's plan was used. Additional bolts up to 40 feet long were installed on each side of the corners, angled to intersect and anchor behind cross-cutting joint planes. Vertical bolts up to 40 feet long were installed from the elevation 1200 level, on four-feet-centers around the

outside corners. The layout of additional bolts is shown on PLATES B-14 and B-15.

The blasting plan was revised to reduce the overall size of the blasts and reduce presplit hole spacing to 18 inches. Presplitting from elevation 1200 to 1155 was completed in one lift. Other details of the revised blasting plan were:

Type	Dia.	Spacing	Depth	Stem	Powder
PS	3"	18"	45'	4'	Detagel and Unigel
Prod	3½	7'x 7'	15'	6'	ANFO

Blasting resumed on 19 June below elevation 1200 with much improved results. Excavation was completed to invert level by 26 June. Installation of pattern rock bolts, drains, and shotcrete was completed around the portal corners. Blasted rock was pushed back up to the portal faces to a level four feet below springline to form an access ramp and work platform for construction equipment. The two roadheaders were moved into position in front of tunnels 1 and 2 with excavation of the top headings scheduled to begin in early September 1990.

6.4.4 Disposition of Excavated Materials. Initially rock excavated from the downstream portal was placed in disposal area L-11. Beginning in February 1990 the material was hauled to the proposed site for the new Harlan High School. Blasted rock was also used as fill in the Highway 72 bridge abutment approach ramps.

6.5 Foundation Preparation and Clean-up. Slopes were cleaned using compressed air and water, and hand tools. Water was used sparingly on the more weathered siltstone surfaces. Scaling of loose rock from the surface slopes was accomplished with the excavating equipment as the cut was brought down. The contractor proposed to use high pressure water sprayers (green-cutting), rather than sandblasting, to remove latency and rebound material which accumulated at the bottom of the slope during shotcrete application. This method was used with good results. Cleaning of the cold-joint was further improved upon by placing two-by-eight- feet plywood sheets along the bottom of the slopes being shotcreted. The plywood reduced the accumulation of rebound material and kept the exposed bottom edge of the welded wire reinforcement cleaner. About 15 minutes after shotcrete application, the plywood was removed and the joint area was green-cut. This procedure worked very well and green-cutting, instead of sandblasting, was approved for continued use.

6.6 Rock Reinforcement. Downstream portal slopes were reinforced with rock dowels and rock bolts as shown on PLATES B-11 through B-15. Both rock dowels and rock bolts were epoxy coated No. 7, grade 60, fully threaded steel bars manufactured by the Dywidag Company.

Rock dowels were installed on ten feet spacing along the more weathered, upper portion, of the rock slopes. Dowels were grouted with Conbextra-S non-shrink grout and were not stressed. Dowels were installed within 24 hours of exposure of the excavated face.

Pattern rock bolts, were installed on a 10 by 10 feet staggered pattern. Additional bolts, up to 25 feet in length, were installed as necessary. Rock bolts were anchored with Fosroc Lokset resin cartridges and stressed to 30 kips. Bolts were installed within 48 hours of exposure of the excavated face. The resin manufacturer's data indicated that with ⅞-inch bolts and 1¼-inch holes, the 1⅛-inch resin cartridges would "yield", or encapsulate, 16 inches of bolt per 12-inch cartridge including a 15% loss which was considered to be typical. In practice, however, a 12-inch cartridge would yield only about 12 inches of bolt encapsulation. At first it was suspected that the resin loss was occurring as resin was forced into cracks in the rock. While that may have been true in some instances, the difference was attributed primarily to variations in hole diameter. Measurements with a hole gauge indicated holes to be the correct 1¼-inch diameter at the bottom of the hole, with the diameter increasing slightly toward the collar. This lower than anticipated yield was obvious from the beginning, when resin failed to show at the rock surface as a bolt was inserted. Nine 12-inch cartridges were required for each ten feet long bolt. For longer bolts, the number of resin cartridges was increased accordingly.

6.6.1 Rock Bolt Testing. Specifications required two types of rock bolt testing, pull-out tests and load cells. Two pull-out tests were conducted at the upstream portal area early in the bolting program to check the strength of the anchorage system and insure the adequacy of bolting procedures. Three load cells were installed on downstream portal surface bolts to monitor long-term performance. For both types of tests, only the fast-set anchor zone resin cartridges were used. Results of the pull-out tests are shown below. Load cells are discussed in Section 6.9.

6.6.1.1 Pull-Out Tests. Test bolts were to be stressed to 1½ times the yield strength of the bolt, or to failure, whichever was less. The yield strength of a No. 7 grade 60 bolt is 36 kips, therefore the maximum test load was to be 54 kips. In the first two tests elastic deformation of the bolts occurred before failure of the anchorage. Since the ultimate strength of this type of bolt is 52½ kips, the maximum load applied to the remaining three test bolts at the upstream portal was reduced to 42 kips. The tensioning jack was calibrated against a load cell before each test. Both tests were conducted in hard, unweathered, siltstone using ten feet long, No. 7, grade 60 bolts. Bolt elongation was measured, where recorded, using a hand held scale. Drill hole diameters were 1¼-inches. Resin cartridges were 1⅛-inches in diameter by 12 inches long. Mr. Gary Greenfield of the Fosroc/Celtite

Company was on site to observe the first two pull-out tests. Test results are tabulated below.

Test No.	Bond* Length	Stress* Length	Jack PSI	Load (Kips)	Strain (Ins)	Remarks
S-1	36-in.	76-in.	1300	10	---	Elastic deform-
			2800	20	---	ation began at
			4100	30	0.47	50 kips, testing
			5600	40	0.59	discontinued
			7000	50	---	
S-2	36-in.	76-in.	1300	10	---	Elastic deform-
			2800	20	---	ation began at
			4100	30	0.30	47.5 kips, test-
			5600	40	0.40	ing discontinued
			7000	50	---	

*Bond and stress lengths are calculated based on the observed yield of 12 inches of bolt encapsulation per 12-inch resin cartridge.

Rock bolt pull-out test results confirmed the adequacy of the 36-inch bond zone used for all surface bolts. All surface bolts were tensioned to 30 kips. Three more rock bolt pull-out tests were made at the upstream portal. Details of these tests are included in Section 7.6.1 of this report.

6.7 Rock Protection. Even though SDI test results were in the 97% to 99% range, some deterioration occurs when this siltstone is subjected to repeated wetting and drying cycles, over a period of a few months. A four-inch minimum thickness of welded-wire-fabric reinforced wet-mix shotcrete was applied within 96 hours of exposure of the excavated face to protect against slaking and weathering.

6.7.1 Shotcrete Mix Design. All shotcrete was the wet-mix type. A water reducing admixture was added to a mix having a one-inch slump. The resulting mix had a slump of about 2½-inches measured at the hopper.

The typical shotcrete mix used on surface slopes was:

Mix SG-6

Cement 850 lbs.	AEA 2 oz. (air-entraining admixture)
Sand 1715 lbs.	WRA 51 oz. (water-reducing admixture)
Stone 1010 lbs.	Water 302 lbs.

Accelerator was added at the nozzle as conditions required.

6.8 Drainage Provisions. Drain holes were drilled and slotted PVC pipes installed on a 12-by-12 feet pattern before shotcrete was applied. Drain holes were 15 feet deep and angled 5° upward. Strip drains were installed as necessary.

Strip drains were Hitek 6, a 10-inch wide by ¼-inch thick geocomposite drain, described as a cuspated high density polyethylene core wrapped in a geotextile filter sleeve, produced by Burcan Industries.

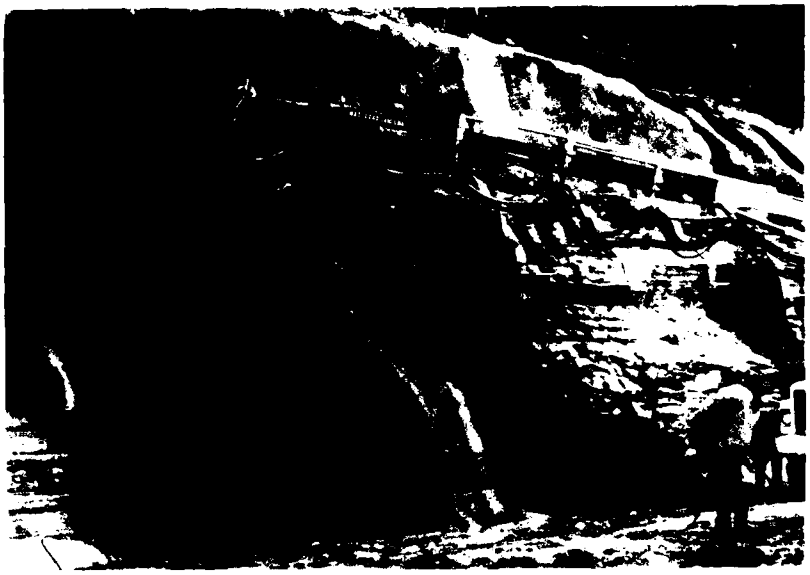
6.9 Instrumentation. Three load cells were installed on downstream portal slopes. Two load cells, L1DS and L2DS, were installed near the downstream portals of tunnels 2 and 3 respectively, on 12 July 1990. These first two installations were observed by Mr. Bill Jewsberry of Slope Indicator Company, the load cell manufacturer. A third load cell L3DS was installed on 14 August 1990. Load cells were monitored daily for the first 60 days after installation and while excavation was within 80 feet, and weekly thereafter for the duration of all tunnel excavation.

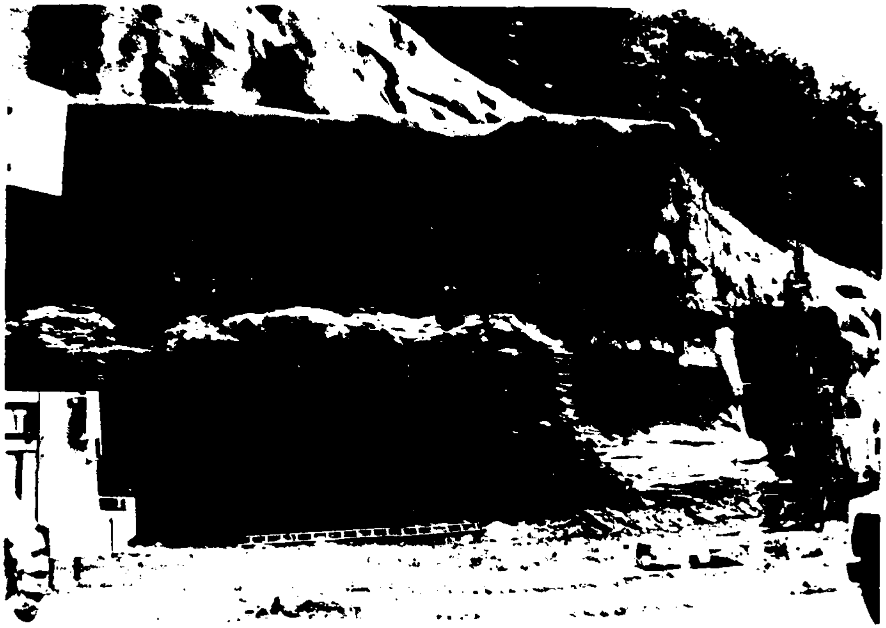
The contractor was required to give immediate notification if a load cell reading was five kips greater than the previous reading. Load cells 1, 2, and 3 were installed with a 20 to 25 kip lock-off load, and showed total increases of only about four kips during the monitoring period. Graphs of load cell readings are included in Appendix I, PLATES I-24 through I-31.

6.10 Foundation Approval and Mapping. Immediately after exposure, portal slopes were inspected by a Corps of Engineers geologist, at which time additional scaling and rock bolting was directed as necessary. Foundation approval was given after final clean-up, before shotcrete was applied. Maps of the downstream portal slopes are included on PLATES B-16 through B-20.

6.11 Possible Future Problems and Recommended Observations. On 23 January 1992 cracks were first noticed in the shotcreted backslope above the tunnel 3 corner, from about elevation 1260 to 1240. Study of geologic maps and construction photographs indicated the cracking occurred along a smooth, high-angle joint face. The cracked shotcrete showed about five inches displacement, which was apparently caused by a buildup of water pressure due to frozen drain holes. The location of the electrical substation, which supplied power to the tunnels, blocked access by shotcrete equipment. As a preliminary fix, the slope was reinforced with 15 additional rock dowels in May 1992. The area became accessible for completion of the remedial work in October 1992. Laborers used jackhammers to remove cracked shotcrete. Inspection of the underlying rock surface indicated that the shotcrete had cracked and separated from the rock surface along the smooth joint face, and no rock movement was involved. The rock surface had remained mostly unweathered and fresh. Additional drains were installed and new shotcrete applied.

Similar shotcrete cracking can be expected in the future. Repair may be dangerous and difficult because of the steepness of the slopes and limited access.





Tunnel 1 corner, from elevation 12[illegible]. Tunnel centerline and elevation 12[illegible] are painted on face. Note loss of corner back to the joint plane. May 19[illegible]

Downstream portal area. August [illegible]

7. **Upstream Portals.**

7.1 Excavation Grades - Design and As-Built. The contractor's surveyor developed a stationing system whereby cross-sections could be made perpendicular to the vertical backslope. All layout and mapping above elevation 1210 utilized this stationing system. Baseline locations are shown on PLATE C-1.

Baseline A = Station 3+20.5
Baseline B = Station 2+00
Baseline C = Station 0+79.5

7.1.1 Overburden. Overburden slopes were designed and constructed at 1V:1H, as shown on the general plan of the upstream portal, PLATE C-1. Because of changes to the underlying rock slopes, the overburden slope extended slightly higher up-hill than originally planned.

7.1.2 Rock.

7.1.2.1 Backslope. The slope was designed to be 2V:1H in weathered rock. A 10-feet-wide bench was to be created where the top of rock line intersected the vertical slope near elevation 1270. Below this bench the vertical slope extended down to tunnel invert at elevation 1168.

Seven air-track holes were drilled to determine the elevation of harder rock along the vertical portal backslope. Harder rock was found to be about 10 feet below the design bench elevation. Based upon these findings, the upstream portal design was changed in the following ways:

1. Vertical slope remained in design location, but lowered approximately 10 feet, to begin in harder rock.
2. The bench, where the vertical slope intersected the hard rock surface, was widened from 10 to 15 feet.
3. 2V:1H slopes were created in hard siltstone and the overlying sandstone, upslope from the 15-ft. bench.
4. On 2V:1H slopes, a 10-feet-wide bench was created at the top of each lift.
5. In continuing development of the vertical face which extended down to tunnel invert level, vertical presplit lines were offset three feet at the top of each lift.

Lowering the bench to begin in less weathered rock was, in large part, a safety consideration. The intent was to reduce the chances of slope failures and rock fall from the top of the vertical slope, which would eventually be about 100 feet directly above the working surface. These changes increased the amount of clearing and excavation above the portals, and increased the tunnel lengths by about three feet. Design and as-built cross-sections are shown on PLATE C-10.

7.1.2.2 Side Slopes. Side slopes were designed and constructed on 4V:1H.

7.1.2.3 Nosings. Three nosings project from the backslope to channel water flow into the tunnels. Each nosing is about 34 feet wide at the back, 20 feet wide at the tip, and 130 feet long. Nosings are about 42 feet high with nearly vertical sides. Nosings consist of rock left in placed during portal excavation, protected by a covering of shotcrete or concrete. The concrete portion of nosing 2 also supports the Highway 38 bridge. Nosing sections and details are included on PLATES C-11 through C-13.

7.2 Dewatering Provisions. Groundwater entering the upstream portal excavation was limited to small seeps occurring at the overburden/rock contact and along bedding planes and joints. The total amount of groundwater seepage was negligible compared to surface runoff.

As the excavation progressed downward below the level of existing Highway 38, about elevation 1200, control of surface runoff became more difficult. Water collected in the portal area during periods of rainfall. Ponded water interfered with work activities, including instrumentation readings, since the muddy water could not be disposed of in the river. After waiting for the suspended solids to settle out, the water was pumped into Clover Fork. Eventually, as the tunnels top headings were completed, water was piped through a tunnel to the downstream portal area and processed through the water treatment plant, before being discharged into Clover Fork.

7.3 Overburden Excavation. Initial clearing of the upstream portal area was done in January and February 1990. Additional clearing which was required because of changes to the rock slopes was done in May 1990. Much of the overburden was removed in conjunction with adjacent Highway 38 excavation which began in March and was completed by the end of July 1990.

7.3.1 Disposition of Excavated Material. Overburden materials from the upstream portal area were placed in the H-2 disposal area.

7.4 Rock Excavation. Rock excavation began at the upstream portal on 28 June 1990 and was completed on 4 April 1991. Blasting began at the top of the slope in sandstone at about elevation 1321, and continued down to tunnel invert level at elevation 1168. Ingersoll Rand ECM 350 air-track drills with 750 CFM air compressors were used to drill blast holes.

Above elevation 1210, blasting methods were similar to those used on the Highway 38 road-cut on either side of the portal. Below elevation 1210, more controlled blasting techniques were used to minimize blast damage to the portal nosings.

7.4.1 Disposition of Excavated Materials. A Caterpillar 977L endloader loaded shot rock directly onto Euclid R50 dump trucks. The material was hauled to the H-2 disposal area, stockpiled for later use as embankment fill, or used to backfill areas in the Highway 38 subgrade which were over-excavated to remove unsuitable material.

7.4.2 Blasting Above Elevation 1230.

7.4.2.1 Presplit Blasting. In developing the upstream portal back slope, the angled presplit holes ran approximately parallel to the existing ground surface only a short distance away. Firing the presplit line in a separate operation before the production blast disturbed the remaining rock and made it difficult to drill the production blast holes. If production holes were drilled before the presplit shot, holes were cut off and could not be loaded. For these reasons, the presplit and production blasts were usually fired in one operation, separated by millisecond delays.

Presplit holes were 2¾-inches in diameter, drilled on 36-inch centers, with a maximum depth of 30 feet. A typical presplit blast contained 30 holes. To keep blast vibrations down, a maximum of 15 holes were fired per delay period, with a 17-millisecond surface delay between groups of holes. Holes were loaded with Detagel, primed with detonating cord, and initiated with an instantaneous electric blasting cap. Using four feet of crushed gravel stemming, this resulted in 100.9 pounds of explosives per delay period.

The condition of the final slopes formed by presplit blasting was generally good. Back break occurred in areas where joints intersected the rock face at an angle of about 15° or less. Several blocks fell out from the face leaving overhangs which were removed or bolted.

7.4.2.2 Production Blasting. Production holes were 3½ and 4-inches in diameter, drilled on a six-by-six, seven-by-seven, or eight-by-eight feet square pattern, with a maximum depth of 30 feet. The number of holes per shot varied. Holes drilled adjacent to the presplit lines were shortened so that they would be no closer than six feet to the presplit line at the bottom of the hole. Holes were loaded with Iremite and ANFO with one pound cast primers and non-electric caps. Holes were stemmed with six to seven feet of crushed gravel. Powder factors ranged from 1.2 to 1.7 pounds per cubic yard. To keep blast vibrations down, the amount of explosives was limited to less than 85 pounds per delay period. Seismographs were set up for all blasts to monitor vibration levels at nearby structures.

7.4.2.3 Excavation Summary, Problems, and Treatment. Blasting exposed joints of very high continuity which intersected the portal backslope at a 15° angle, and dipped toward the open excavation (N 40°E, 75°SE). Zones, up

to 2.4 feet thick, of very closely spaced (approximately ½-inch) joints were noted. These are shown as joints number 15, 16, and 20 on the geologic map of the upstream portal slopes, Plate C-10. The joints are coated with very soft, residual silty clay, are slightly rough to smooth and are not healed.

A revised bolting plan, developed with the assistance of District Engineering and Construction Divisions, was implemented to provide additional support for rock prone to spalling and down-dip gravity sliding along joint faces. Bolt spacing was reduced from ten-by-ten feet to five-by-five feet, and bolts were angled 5° above horizontal. Bolts were lengthened as necessary, up to a maximum 25 feet length, to provide anchorage about five feet behind the joint planes. As-built bolt locations are shown on PLATES C-14 and C-15.

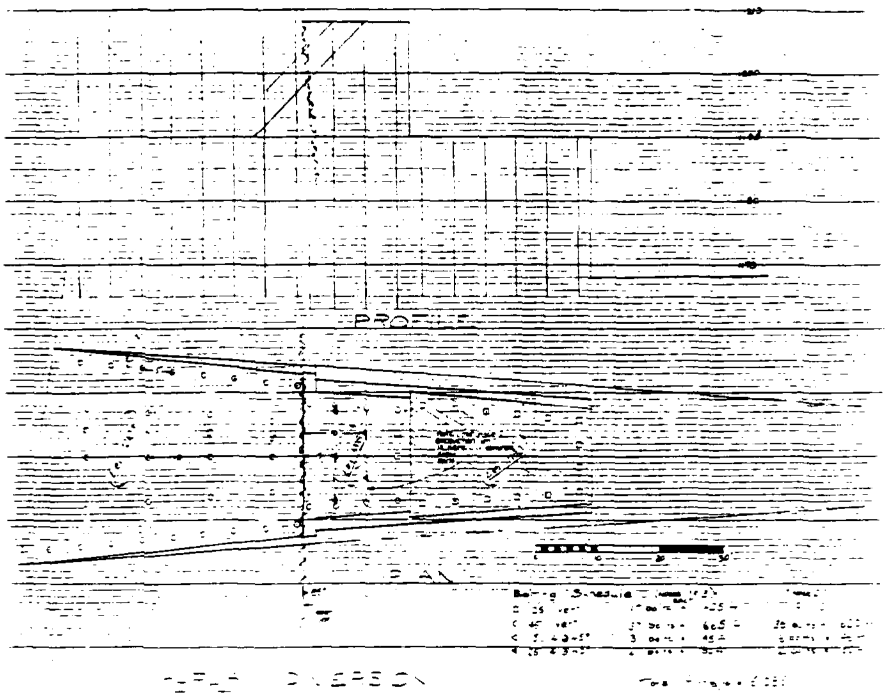
Joint mapping and projection of strike identified advantages for the use of longer bolts between stations 0+60 and 1+00, elevations 1237 and 1242. 15-feet long bolts were installed to anchor three to five behind the joint plane. Joint filling caused difficulty for resin insertion, clogging the drill hole and requiring repeated reaming to clear the hole. Drilling holes without water produced better results.

Although no actual damage to the shotcrete was observed during blasting, several shotcrete undercuts developed behind template. One occurred near station 1+85 in an area where fallouts had occurred during previous excavation. Other fallouts were noted at stations 1+00, 2+00 and 2+30. Short rock dowels were installed in each fallout area prior to shotcrete backfilling. A five-by-five feet pattern of bolts up to 25 feet long, was installed as in the previous lift.

7.4.3 Blasting Below Elevation 1230.

7.4.3.1 Nosing Reinforcement Prior to Blasting. Nosings were reinforced with vertical bolts ranging in length from 15 to 45 feet, anchored below tunnel invert level to elevation 1165-1163. Bolts were installed on five feet centers around the perimeter of the nosings, and on approximately six-by-ten feet spacing on interior surfaces of the nosings. Bolts were also installed on 45° angles to anchor behind high angle joints.

The bolt installation procedure required 2½-inch diameter drill holes with a five feet anchor zone at the base. A threaded coupling was used on bolts longer than 40 feet. After grout in the bond zone had cured, the remainder of the hole was filled with grout. Finally, the bolt was tensioned to 30 kips and the load locked off.



Reinforcement plan for upstream portal nosings.

7.4.3.2 Blasting Plan. Dr. Calvin Konya of Precision Blasting Services in Montville, Ohio was called in as a blasting consultant. Controlled blasting techniques were implemented to minimize damage to the upstream portal nosings. Blasting methods and results are summarized below.

7.4.3.3 Blasting Sequence. Presplit holes were drilled for the full 42 feet depth of the nosings and, after stemming the lower portion of these holes, presplit and production blasts were fired in two lifts of about 21 feet each. Following presplitting one, two, and three row production blasts were used to excavate rock between the nosings.

7.4.3.4 Presplit Blasting. Presplit holes were 2½- inches in diameter, drilled on 18-inch centers. Initially holes were loaded with eight sticks of ⅞-inch diameter by 12-inch long cartridges of "Red-E-Split A" taped onto 50-grain detonating cord and spaced 34 inches center-to-center. With two feet of stemming this produced a weight of 0.116 pounds of explosives per foot of hole. Because of excessive fly rock and heaving, loading was later reduced to 0.10 and eventually 0.07 pounds per foot by increasing spacing between sticks and leaving a four feet air space above the upper stick. Presplit holes were fired simultaneously with high precision blasting caps.

7.4.3.5 Production Blasting. Production holes were three-inches in diameter, drilled on a five-by-seven feet rectangular pattern, and 20 to 22 feet deep. Production holes

were loaded with two-inch diameter Iremite E, and stemmed with about four feet of crushed stone. A row of buffer holes was used between the production holes and the finished slope. These were drilled on four feet centers parallel to, and three feet away from, the presplit wall. The buffer holes were 2½-inches in diameter and depths varied depending upon the slope of the adjacent presplit wall. Buffer holes were loaded with 1½-inch diameter Iremite E. Production shots were fired with non-electric caps and delayed to open near the center and fire progressively toward each side.

7.4.3.6 Problems and Solutions. Blasting and excavation was complicated by frequent movements of nosing blocks sideways along bedding planes and high angle joints. Extensive bolting and changes to the blasting plan resulted in some improvement.

As blasting began between nosing 1 and 2, lateral movement of the rock mass of nosing 1 occurred along a bedding plane at elevation 1190. The nosing tip rotated in an upstream direction and offsets as much as 1.4 feet were measured. The horizontal movement cut off presplit drill holes which had not been loaded and fired. Portions of the two-inch thick shotcrete "flash-coat" cracked during blasting and had to be removed.

The tip of nosing 2 also shifted during blasting. The displaced block contained very closely spaced joints which dipped 70 degrees toward the open excavation. Unlike the other two nosings, nosing 2 had no bench out in front at elevation 1190 which would serve to stabilize the displaced block. The disturbed rock was determined to be a safety hazard and a backhoe was used to remove it. About 120 cubic yards of additional concrete was required to replace it. Ten additional 20-feet-long bolts were installed in the end of the nosing between elevations 1200 and 1190.

Two smaller blasts of one row each were made in an attempt to reduce movements of adjacent nosings, without significant improvement. Blasting consultant Dr. Konya recommended returning to two row breakup shots between nosings, and this was done.

Two other changes were made to reduce movement of the nosings during blasting. To reduce bolt breakage, stressing of bolts was discontinued. Bolt angles were increased to 30° downward from horizontal to provide better anchorage across bedding planes. These changes may have helped slightly, but rock displacements continued to occur.

As excavation of the nosings progressed, it became apparent that the contract requirement of shotcreting the exposed rock surface within 96 hours would have to be waived. When shotcrete was applied before blasting on the opposite side of a nosing, shifting of the rock mass would crack the shotcrete

to the extent that it had to be removed and new shotcrete applied. For this reason, shotcrete was delayed until adjacent blasting was complete. To prevent weathering of the siltstone a "flash coat", an approximately one-inch-thick layer of protective shotcrete, was applied as soon as possible after exposure, to be followed by installation of rock anchors, welded wire fabric, and the full four-inch thickness of shotcrete at a later time. Blasting of the upstream nosings was completed in April 1991. The nosings were surveyed so that final trimming requirements could be determined. Trimming was necessary and the contract was modified to accomplish this. A hoe-ram was used to trim nosings to within required lines to allow clearance for concrete forms. To reduce trimming requirements, the position of nosing 1 was rotated one degree upstream from its design position. Nosings 2 and 3 were not changed.

7.5 Foundation Preparation and Clean-up. Loose rock was removed by a backhoe as the slopes were brought down. Final cleaning was by compressed air and water, and hand tools.

7.6 Rock Reinforcement. Pattern rock dowels and bolts were installed as at the downstream portals, except that horizontal spacing was decreased from 10 feet to 8.6 feet. The general bolting details are shown on Plate C-16. In some areas the bolting pattern was changed and longer bolts installed, as described in Section 7.6 of this report. Rock bolt materials were the same as used elsewhere on the project.

7.6.1 Rock Bolt Testing. Three rock bolts were pull tested to confirm the adequacy of the anchorage system. Test results are shown below.

Test No.	Bond Length	Stress Length	Jack PSI	Stress (Kips)	Strain (Ins)	Remark.
S-3	36 in.	76 in.	----	10	0.10	No failure.
			----	20	0.22	
			----	30	0.40	
			----	40	0.81	
			----	42	1.15	
S-4	24 in.	88 in.	----	10	0.13	No failure.
			----	20	0.32	
			----	30	0.50	
			----	40	0.90	
			----	42	1.40	
S-5	26 in.	110 in.	----	10	0.25	No failure.
			----	20	0.38	
			----	30	0.52	
			----	40	0.78	
			----	42	0.94	

Bond and stress lengths are calculated based on the observed yield of 12 inches bolt encapsulation per 12-inch resin cartridge. No failures resulted with bond zones as short as 24 inches and loads as high as 42 kips. Pull-out tests confirmed the adequacy of the 36-inch bond zone used for surface bolts. All surface bolts were tensioned to 30 kips.

7.7 Rock Protection. As at the downstream portals, siltstone slopes were shotcreted to protect against weathering. The Cawood sandstone exposed at the top of the slope was not shotcreted.

7.8 Drainage Provisions. As at the downstream portal, slotted PVC pipe lined drain holes were installed 15 feet deep, angled 5° upward, on a 12-by-12 feet pattern. Strip drains were installed as needed to drain joints which intersected the slope face.

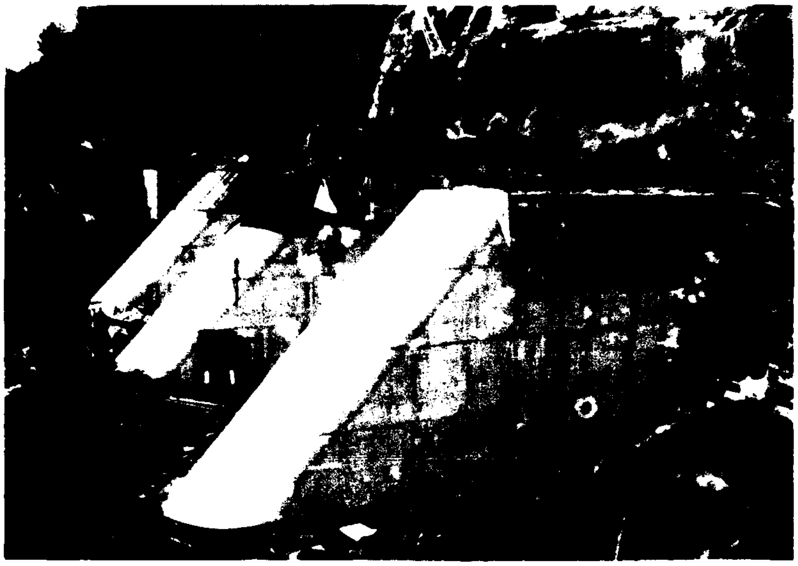
7.9 Instrumentation. Load cells L4US, L5US, and L16US were installed with a lock-off load of about 25 kips. L4US and L5US showed gradual increases and leveled off at 30 to 34 kips. L16US showed a gradual decrease and leveled off at 19 kips. Graphs of load cell readings are included in Appendix I, PLATES I-24 through I-31.

7.10 Foundation Approval and Mapping. Immediately after exposure, portal slopes were inspected and additional scaling and rock bolting was done if necessary. Slopes were mapped before wire mesh shotcrete reinforcement was installed. Foundation approval was given after final cleanup, immediately before shotcrete application. Geologic maps of the upstream portal slopes are included on PLATES C-19 through C-23.

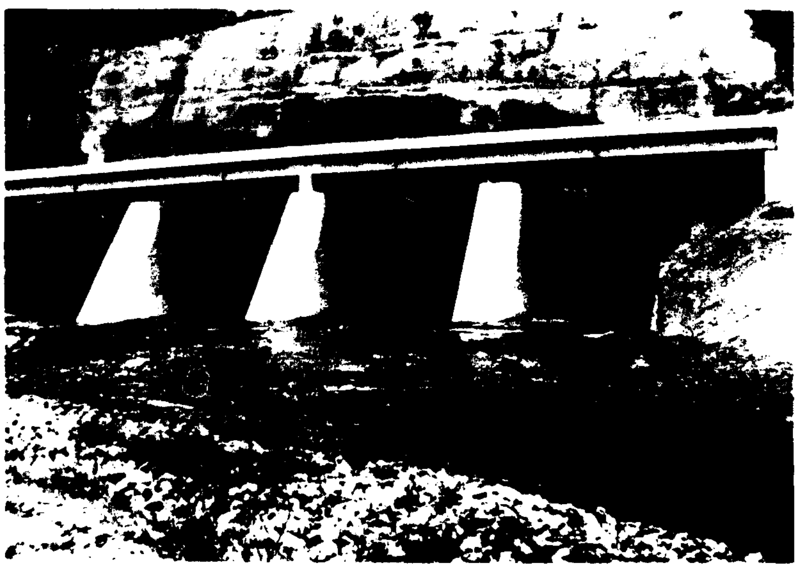
7.11 Possible Future Problems and Recommended Observations. As has already occurred at the downstream portal, freezing of drain holes could lead to shotcrete cracking.

Upstream portal slope. Strip drains installed along joints, elevation 1275 to 1260. 31 July 1990

Top of nosing 1, elevation 1210, with vertical bolts laid out. View southwest across upstream portal area. 13 November 199[illegible]



[illegible] with concrete [illegible]
[illegible] 27 February 194[illegible]



[illegible] and [illegible] after
[illegible]

8. Tunnels

8.1 Excavation Grades - Design and As-Built. Each of the four tunnels is an inverted "U" shape, 34 feet wide and 32 feet high. An over-excavation tolerance of six-inches outside the "B" line was allowed. When surveys indicated that an area had been undercut, it was trimmed with a roadheader. Overcut areas were filled with shotcrete to within the six-inch tolerance.

The tunnels range from 1836 to 2059 feet and average 1941.5 feet in length. Having a uniform grade of one foot vertically in 162.5 feet horizontally, the tunnels slope about 12 feet from upstream to downstream.

8.2 Overburden Excavation. All overburden was removed during development of the tunnel portals.

8.3 Rock Excavation-Top Headings. To minimize disturbance of rock in the tunnel crown, specifications required that the top heading be excavated by a roadheader. The top heading consisted of the semi-circular area above the tunnel spring line and two feet below spring line for the Dosco roadheader, and four feet below spring line for the Paurat roadheader. The Dosco roadheader excavated a total of 32,841 cubic yards and the Paurat a total of 132,329 cubic yards of rock from the top headings of the tunnels.

8.3.1 Dates. Roadheader excavation of the top headings began on 4 September 1990 and was completed on 23 March 1992. The chart "Tunnel Excavation Methods and Dates" on page 65 summarizes the dates of all excavation activities in the tunnels.

8.3.2 Methods and Equipment. The tunnels were driven from the downstream end up slope to ensure that water would drain away from the face. An electrical substation to supply power to the roadheaders was established at about elevation 1230, on the backslope above tunnel 4.

The contractor selected the size and type of roadheader based upon rock test data provided in the specifications, roadheader manufacturers recommendations, production rates, and scheduling requirements among other factors. A 120-ton Paurat E-242-B and an 83-ton Dosco Mk3 roadheader were used for excavating the top heading and trimming the sides of the bottom headings. During the time that both roadheaders were in use excavating the top headings, September 1990 through August 1991, the larger Paurat outperformed the Dosco by about 2.7 to 1 in total cubic yards of rock excavated. Because of excessive downtime the Dosco roadheader was removed from top heading excavation 1490 feet into tunnel 2. The Paurat completed the remainder of the top headings, and the Dosco was used only in trimming the bottom headings to finish grade.

Roadheader specifications are shown on the following chart.

Roadheader Data		
Manufacturer	Dosco	Paurat
Model No.	MK3	E 242B
Weight	83 metric tons (91.5 short tons)	120 metric tons (132 short tons)
Length	12.2 meters (40 ft)	16.6 meters (54.4 ft)
Height (Main Body)	2.95 meters (9.7 ft)	3.94 meters (12.9 ft)
Max. Cutting Height	6.1 meters (20 ft)	7.5 meters (24.6 ft)
Utilized Cutting Height (Approx)	5.8 meters (19 ft)	6.4 meters (21 ft)
Max. Cutting Width	7.2 meters (23.6 ft)	8.9 meters (29.2 ft)
Cutter Motor Size	276 kW (370 hp)	300 kW (402 hp)
Max. Torque at Cutting Head	49.6 kNm (36,586 ft lb)	132.4 kNm (97,653 ft lb)

8.3.3 Roadheader Excavation Rates. In calculating roadheader excavation rates, if a roadheader was in use for any part of a day, it was considered as a full operating day with no adjustment for rock bolting time, shotcrete time, or equipment downtime. Actual excavation rates would be slightly higher than indicated.

8.3.3.1 Dosco Excavation Rates. The Dosco roadheader worked 207 days (4010 hours) during the period from 4 September 1990 to 15 August 1991, excavating a total of 32,841 cubic yards of rock.

$$32{,}841 \text{ CY} / 4010 \text{ hours} = 8.19 \text{ CY} / \text{hour}$$

Assuming full utilization of the 370 horsepower cutter motor:

$$\frac{8.19 \text{ CY} / \text{hour}}{370 \text{ Hp}} = 0.022 \text{ CY} / \text{hour} / \text{hp}$$

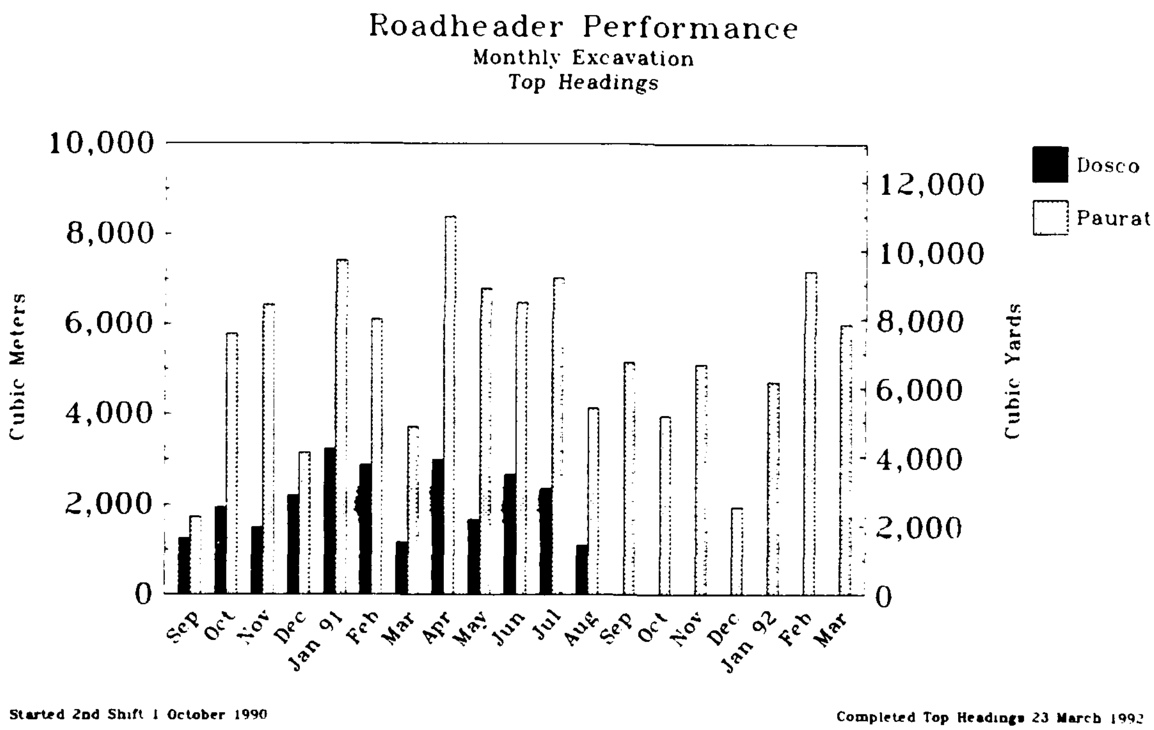
8.3.3.2 Paurat Excavation Rates. The Paurat roadheader worked 348 days (6820 hours) during the period from 4 September 1990 to 23 March 1992, excavating a total of 132,329 cubic yards of rock.

$$132{,}329 \text{ CY} / 6820 \text{ hours} = 19.40 \text{ CY} / \text{hour}$$

Assuming full utilization of the 402 horsepower cutter motor:

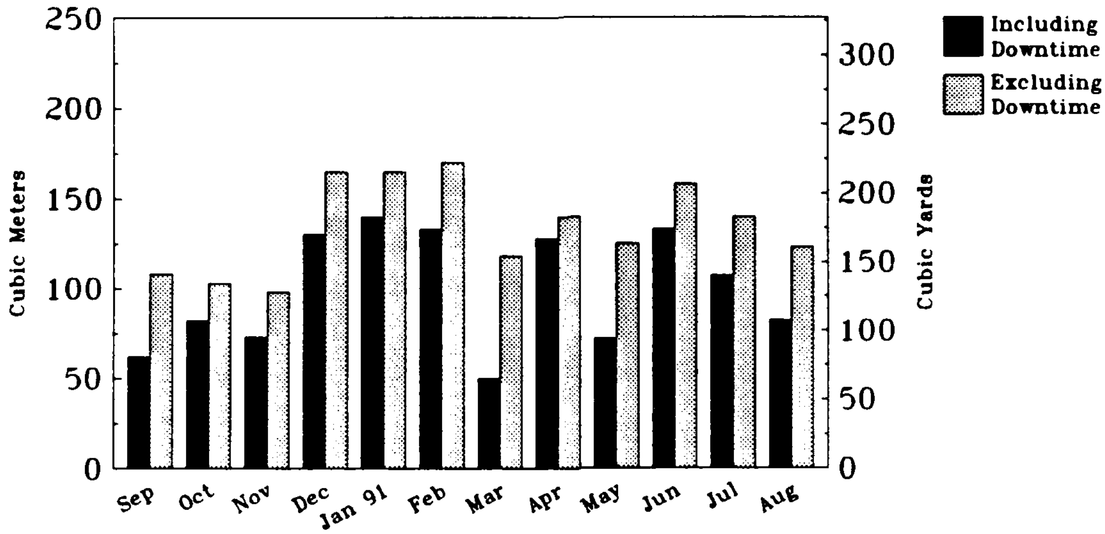
$$\frac{19.40 \text{ CY} / \text{hour}}{402 \text{ Hp}} = 0.048 \text{ CY} / \text{hour} / \text{hp}$$

8.3.4 Roadheader Performance Graphs and Chart. Roadheader performance graphs, which illustrate daily and monthly excavation data, are shown below.



Dosco Roadheader

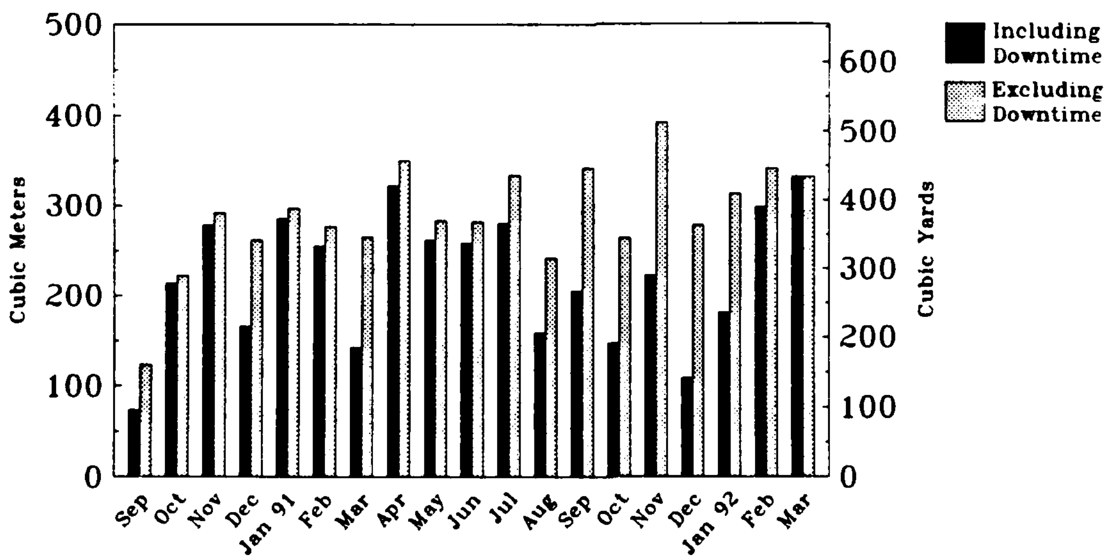
Average Daily Excavation
Top Headings



Started 2nd Shift 1 October 1990.

Paurat Roadheader

Average Daily Excavation
Top Headings



Started 2nd Shift 1 October 1990.

Completed Top Headings 23 March 1992

The total linear feet of tunnel and cubic yards excavated by each machine are shown on the following chart.

Roadheader Excavation
Top Headings

	Dosco Model Mk3			**Paurat** Model E242B		
Month	Linear Feet	Cubic Yards	CY/hp	Linear Feet	Cubic Yards	CY/hp
Sept (90)	84	1,624	4.4	103	2,250	5.6
Oct	131	2,532	6.8	346	7,557	18.8
Nov	101	1,952	5.3	385	8,408	20.9
Dec	148	2,861	7.7	188	4,106	10.2
Jan (91)	218	4,214	11.4	444	9,697	24.1
Feb	194	3,750	10.1	366	7,993	19.9
Mar	78	1,508	4.1	222	4,848	12.1
Apr	201	3,885	10.5	503	10,986	27.3
May	112	2,165	5.9	407	8,889	22.1
Jun	199	3,847	10.4	388	8,474	21.1
Jul	159	3,073	8.3	421	9,195	22.9
Aug	74	1,430	3.9	247	5,394	13.4
Sep	--	---	--	308	6,727	16.7
Oct	--	---	--	237	5,176	12.9
Nov	--	---	--	306	6,683	16.6
Dec	--	---	--	117	2,555	6.4
Jan (92)	--	---	--	282	6,159	15.3
Feb	--	---	--	430	9,391	23.4
Mar	--	---	--	359	7,841	19.5
TOTALS	1,699	32,841	--	6,059	132,329	---

8.3.5 Pick Consumption. Most of the picks used were manufactured by Kennemetal, Inc. Experiments with a longer pick manufactured by American GTE, Inc. proved unsuccessful. While the longer pick cut more rock per operating hour, the added leverage with the longer pick caused damage to the bit block. In addition, the carbide cutting elements were frequently damaged. Any gains realized from use of the longer picks were offset by longer periods of downtime and fewer operating hours. The experiment was abandoned and the use of shorter picks resumed.

Picks located at the tip and back of the cutting head received the most wear and were the most frequently replaced. At times the contractor replaced completely worn out picks with used, but less worn, picks and this made pick usage rates difficult to determine. A pick usage rate, believed to be indicative of overall rates, was recorded in February 1992 when the Paurat roadheader used 301 picks in excavating 9,391 cubic yards (430 linear feet) of rock. This equals 31.2 cubic yards of rock excavated per pick.

It was anticipated that, when excavating through the beds of hard very-fine-grained sandstone, the roadheader operator would "sump-in" above and below the bed and then break off the hard layers. In practice this was not often done. To avoid having to back-up the roadheader, the operator cut "head-on" into the hard beds. This resulted in increased wear on the picks and increased the pick usage rates.

8.3.6 Construction Summary. The downstream portal face was prepared to begin roadheader excavation by painting the 17-feet radius of the B-line. Crown bolts, 16 feet long No. 8 bolts, were then installed as shown on Plate B-15. Following crown bolt installation, the typical sequence of operations for the top headings was:

1. Advance roadheader five feet to establish tunnel brow
2. Remove loose rock
3. Conduct initial profile and X-section mapping
4. Trim with roadheader if necessary
5. Remove loose rock
6. Install rock bolts
7. Install instrumentation, if required
8. Conduct final profile and X-section mapping for "as-built" documentation
9. Wash rock surfaces
10. Perform geologic mapping
11. Apply shotcrete

The above procedure was repeated until 10 to 25 feet of heading and a safe working area had been established, after which time the heading was advanced in increments of about 25 feet.

Following the completion of the first 100 feet of top heading the ventilation, electric power, and lighting were installed.

The laser alignment system was also installed to provide line and grade control for roadheader operation.

The roadheader automatic guidance system was never operative on this project. Control of top heading excavation was maintained using five to seven lasers, mounted one foot inside the tunnel B-line, to assist with the manual operation of the roadheader.

Upon completion of the first 100 linear feet of tunnel, normal shift work was initiated for the various activities; two 10-hour production shifts per day. Normal hours of activity were from 0700 to 1730 hours for the day shift, and from 1900 to 0530 hours for the night shift, with scheduled maintenance between shifts.

The original excavation plan provided for roadheader excavation and rock bolt installation during both shifts, and the application of shotcrete during the day shift only. The general procedure which gradually evolved was to rock bolt once each day, at the end of the night shift or the beginning of the day shift. This met the contract criteria for installing bolts without post-tensioning, and also kept the roadheader operator under a bolted roof at all times.

8.3.7 Disposition and Processing of Materials. Roadheader cuttings were disposed of at the L-11 disposal area and the new Harlan High School site, or were utilized as fill for the Hwy 72 bridge abutment, the Hwy 38 road subgrade, or the diversion embankment. The only processing necessary was moisture control, allowing the material to air dry after rainfall before continuing the placement of compacted fill.

8.4 Rock Excavation-Bottom Headings.

8.4.1 Dates. Bottom heading excavation began on 13 April 1991 and was completed on 26 June 1992. The chart "Tunnel Excavation Methods and Dates" on page 65 summarizes the dates of all excavation activities in the tunnels.

8.4.2 Methods and Equipment. The contractor was allowed to choose the method of bottom heading excavation, subject to the approval of the Contracting Officer. To prevent blast damage to the downstream portal corners, the outermost few feet of each bottom heading was excavated with a roadheader. The remainder of the bottom heading was blasted. Ingersoll Rand ECM 350 air-track drills were used to drill the blast holes. A side-dump endloader loaded muck onto 16-cubic yard dump trucks for transport to stockpile or disposal areas, or directly to placement as fill in the diversion embankment.

About two feet of rock was left along the sidewalls which was later trimmed to final grade with a roadheader. Where necessary, the tunnel floors were also trimmed with a hoe ram or a roadheader.

Bottom heading construction normally followed this sequence:

1. Excavate outermost few feet with roadheader
2. Drill and blast
3. Remove muck with end-loader and trucks
4. Trim sides with roadheader
5. Conduct initial cross-section survey
6. Complete additional trimming if necessary
7. Conduct final cross-section surveys for "as-built" documentation
8. Wash rock surfaces
9. Complete geologic mapping
10. Apply shotcrete
11. Prepare invert for concrete slab placement (trim with roadheader or hoe ram if necessary, install reinforcement and anchor bars, place concrete)

8.4.3 Blasting. Bottom bench blasting began at the downstream end of a tunnel upon completion of the top heading. Test blasting was performed under the direction of Michael Muth of Blasting Consultants Inc., Lyndon, Kentucky. Results were evaluated to establish a general plan for all subsequent tunnel blasting operations. A total of about 100,000 cubic yards of rock were excavated by blasting in the bottom headings.

Blast holes were 2½-inches in diameter. Holes were drilled on a five-by-five feet square pattern with no hole closer than three feet to the finished excavation limit. Blast holes were 10 to 12 feet deep with 4½ to 5 feet of No. 8 crushed gravel stemming.

Wet holes were loaded with 2 by 16-inch Iremite 42 emulsion slurry cartridges. Dry holes were loaded with ANFO. Due to water remaining in the tunnel from construction of the top heading and to surface runoff entering the tunnels from the upstream portal areas, few blasts were dry enough to allow the use of ANFC.

Blast holes were primed with 2 x 8-inch cartridges of Iremite 42 cap-sensitive emulsion with a detonation velocity of 17,000 feet per second. Blast holes were charged with Primadet Nonel non-electric detonators. The shock tubes on the detonators were hooked up to a trunkline of 25 grain E-Cord and initiated with a non-electric device.

The contractor's original blasting plan submittal called for six row blasts. To allow for evaluation of blasting results, a test program was initiated. The first blasts contained only two rows, with blasts gradually increasing in size up to six rows. A seismograph was set up to monitor peak particle velocities at the closest house on Ivy Hill. The heaviest load used was a six row blast with 37 pounds of explosives per delay, which produced good breakage and registered a maximum peak particle velocity of only 0.18 inches per second measured 195 feet away.

With the good results obtained by the first nine blasts, the contractor requested approval to make larger blasts, up to ten rows into a muck pile. Blast No. 10 in tunnel 1 began another test program to show that this could be done without producing excessive vibration and damage to the tunnel walls. Recorded peak particle velocities are dependent upon the distance from the blast to the seismograph and the pounds of explosives per delay period. In designing the blasts, the goal was to keep velocities low by minimizing the pounds of explosives per delay period. To obtain comparable results a seismograph was set up at relatively constant distances, 45 to 65 feet, in tunnel 2.

Through the test program it was demonstrated that ten row blasts containing up to 42 pounds of explosives per delay period could be used without damage to the tunnels. The maximum peak particle velocity recorded was 2.95 inches per second at a distance of 55 feet from the blast. Seismograph readings indicated that the vertical vibration component was usually the largest for any given blast, while the transverse vibration was usually the smallest. There was no damage to shotcrete observed on any tunnel or surface exposures.

The remaining tunnel blasting plan used eight and nine rows of holes with a maximum of 36 pounds of explosives per delay period. Cubic yards per blast ranged from 450 to 533. Powder factors ranged from 1.01 to 1.08 pounds per cubic yard. After a good sequence of operation had been established, two or three blasts were fired each working day.

Depths of blast holes varied. In tunnel 1 blast holes were drilled to two feet above finish grade. The portion of tunnel 2 which was excavated by the Dosco roadheader, from station 10+48 to 25+38, was left four feet above finish grade because the contractor failed to take the Dosco's shallower cut into consideration and drilled blast holes the same depth as in tunnel 1. This left four feet of rock above invert level which was trimmed with a hoe ram. Tunnel 3 blast holes were drilled to two feet above finish grade. Tunnel 4 blast holes were drilled to finish grade to reduce final trimming requirements.

A typical tunnel blasting plan is shown on page 56.

8.4.4 Disposition of Excavated Materials. All blasts larger than two rows produced good breakage and the shot rock was used as fill material for the Hwy 38 subgrade and the diversion embankment. Excess material was hauled to disposal area L-11 and the Harlan High School site.

8.5 Foundation Preparation. Foundation preparation in the tunnels consisted of removing loose rock, installing rock bolt reinforcement (top headings), and washing the rock surface immediately prior to shotcrete and floor slab application.

8.6 Rock Reinforcement.

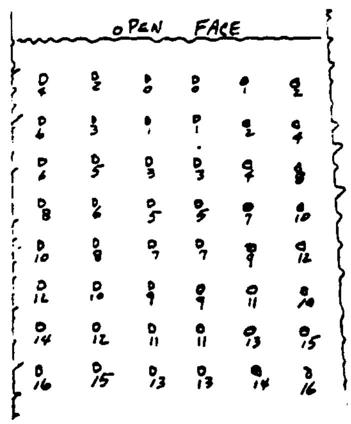
8.6.1 Crown Bolts. Two rows of 16-feet-long crown bolts were installed from the downstream portal face, before roadheader excavation began. Upstream portal crown bolts were installed after roadheader trimming of the bell mouths. Crown bolts were No. 8, epoxy-coated, Dywidag bars grouted with Lokset resin. Crown bolt locations and details are shown on PLATE B-12

TUNNEL # 4

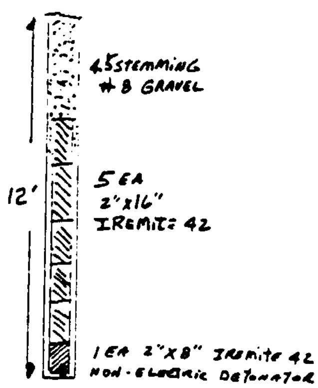
PROPOSED BLASTS

BOTTOM HEADING

HOLE SIZE	2½"
SPACING	5'
BURDEN	5'
TOTAL DEPTH OF EXCAVATION	12'-14'
DRILLED DEPTH	10'-12'
SUB-DRILL	NONE
STEMMING	4.5' #8 GRAVEL
HOLES PER BLAST	48
HOLES PER DELAY	3
LBS PER HOLE	11.44
LBS PER DELAY	34.3
LBS PER BLAST	550
CY PER BLAST	533
POWDER FACTOR	1.03



DELAYED AS SHOWN



8.6.2 Rock Bolts. The tunnels top headings were reinforced with 12-feet long rock bolts installed on a six-by-six feet pattern (six feet between rows of bolts and six feet between bolts within each row) as shown on PLATE D-6. Holes were drilled and the bolts installed by a Tamrock auto rock bolt machine equipped with hydraulic hammer. The automatic resin cartridge insertion system on the rock bolt machine did not work as intended and resin cartridges had to be inserted manually by a laborer working from an elevated work platform. Resin cartridges were held in place in the nearly vertical holes by square plastic clips placed on each cartridge.

Bolt installation was normally accomplished within the time and distance limitations specified, within 20 feet of the advancing face and within 24 hours of exposure, so that stressing of the bolts was not necessary. Each row of seven roof bolts typically took about 30 minutes to install. Bolts which were installed outside these time and distance requirements were stressed to 22 kips, which approximately doubled the installation time.

8.6.2.1 Rock Bolt Testing. Specifications required two types of rock bolt testing. Pull-out tests were conducted early in the bolting program to check the strength of the anchorage system and insure the adequacy of bolting procedures. Load cells were installed to monitor long term performance on ten tunnel bolts. See Section 8.9.1, "Instrumentation", for discussion of load cells.

Five tunnel bolts were pull tested to a maximum load of 42 kips. The tensioning jack was calibrated against a load cell before each test. All tests were conducted in hard, unweathered, siltstone using twelve feet long, No. 7, grade 60 bolts. Bolt elongation was measured, where recorded, using a hand held scale. Drill hole diameters were 1¼-inches. Only fast-set anchor zone cartridges were used. Two different sized resin cartridges were used: 1⅛-inches diameter by 12-inches long, and 1⅛-inches by 26-inches long. Bond and stress lengths shown below are calculated based on the observed yield of 12 inches of bolt encapsulation per 12-inch resin cartridge.

At the time of pull-out test T-3, on 30 November 1990, low temperatures had begun to cause excessively long gel times for the H-90 fast set resin. Some tunnel roof bolts actually slipped back out of the hole because the resin was not gelling quickly enough. Replacement bolts were installed at the contractor's expense. The contractor elected to change to H-35 fast set resin which has a much faster gel time. Test T-3 was intended to be the first bolt tested using the newly acquired H-35 resin. The bolt failed in the bond zone, pulling out 2.4 inches (the limit of the jack ram) with little resistance. After testing it was determined that some of the left over H-90 resin had been placed into an H-35 box. The resin had not gelled when pull tested five minutes after installation. Because of this error, test T3-A was conducted.

Tunnel Bolt Pull-Out Tests

Test No.	Bond Length	Stress Length	Jack PSI	Stress (Kips)	Strain (In.)	Remarks
T-1	24 in.	88 in.	----	10	----	No failure.
			----	20	----	
			----	30	----	
			----	40	----	
			----	42	----	
T-2	12 in.	100 in.	----	10	0.40	Vert. roof bolt, failed at 20 kips due to lack of resin confinement
			----	20	----	
T-3	26 in.	110 in.	----	--	----	Bond zone failed, resin not gelled
T-3A	26 in.	110 in.	1800	10	0.10	Failed at 42 kips
			3050	20	0.20	
			4500	30	0.30	
			6000	40	0.50	
			----	42	----	
T-4	26 in.	110 in.	1700	10	0.05	No failure
			2900	20	0.15	
			4300	30	0.30	
			5900	42	0.55	
T-5	26 in.	110 in.	500	10	0.13	Failed at 32 kips
			2050	20	0.25	
			2400	22	0.30	
			3300	30	0.50	
			----	--	----	

The lowest legitimate pull-out force recorded occurred in test T-5, which failed at 32 kips with a 26-inch bond zone. Tunnel bolts were installed with a minimum 36-inch bond zone and none of the bolts which required stressing failed during stressing to the specified 22 kips. Most tunnel bolts were installed within specified time and distance requirements, so that stressing was not necessary.

8.7 Rock Protection. Shotcreting of finished tunnel surfaces was required within seven days of exposure. A remotely controlled Finn "Robocon" ES-1000, mobile shotcrete rig was used for shotcrete application on all tunnel rock surfaces. A four-inch minimum thickness of steel-fiber-reinforced shotcrete was applied, sometimes in one application, and sometimes in two separate applications. The shotcrete was cored at regular intervals for testing purposes, and these

cores usually indicated actual shotcrete thickness of five to six inches. Over-cut areas were backfilled with shotcrete to within the allowable six-inch tolerance. Shotcrete was usually scheduled to be applied once each week, early on Saturday morning, though roadheader downtime often allowed more frequent application.

The floor of the completed tunnels is protected by a minimum eight-inches-thick concrete slab. Due to over-trimming by the roadheaders and hoe rams, the slab ranges from eight-inches up to about two feet, and averages about one foot in thickness. The floor slab is reinforced with No. 5 reinforcing bars spaced on 18-inch centers. The slab is anchored by No. 6 bars grouted two-feet into rock and placed on seven feet spacing. No drain holes were installed. Details of floor slab reinforcement are shown on PLATE C-13.

8.7.1 Shotcrete Mix Designs. Different mix designs were developed for overhead and side-wall applications. The most significant difference was the use of microsilica in overhead locations. Tunnel shotcrete mix design work sheets are shown below.

Top Headings

SHOTCRETE MIX DESIGNS

Project: Harlan Diversion Contractor: Grassetto/Lucia Date: 9/18/91

Design Strength: 4000 Mix Design No.: TMG-1 Supplier: Mountain Construction Concrete Diversion

Material	Source	Specific Gravity x 62.4	
Cement	Dixie	3.15 x 62.4 = 196.56	✓
Fly Ash	Southeastern	2.30 x 62.4 = 143.52	
Micro Silica	Elchem	2.40 x 62.4 = 149.76	✓
Sand	Whitewater Aggregates	2.66 x 62.4 = 165.98	✓
Sand (Mfg.)	Rogers Group	2.72 x 62.4 = 169.73	
Stone	Mally & Haydon	2.72 x 62.4 = 169.73	✓
Steel Fiber	Novicon	7.30 x 62.4 = 455.52	✓

Material	Weight per C.Y.	Solid Volume	% Moisture	Actual Weight
Cement	800	4.07		800
Fly Ash	–	–		–
Micro Silica	75	.50		75
Sand (Natural)	1700	10.24	5%	1770
Stone	800	4.71	2%	810
Steel Fiber	100	0.22		100
Air (6 %)	–	1.62		–
Water (43gal)	360	5.77		250
Total	3835	27.13		3835

Admixtures		Manufacturer/Type	Break Data	
AEA	oz./cwt		7-day	psi
WRA	oz./cwt		28-day	psi
	oz./cwt		28-day	psi
	oz./cwt		Other	psi

Shotcrete Data

Shotcrete Temperature: Air Temperature: W/C Ratio 0.45

Percent Coarse Aggregate: 32 Slump: 2½ Air Content: 7%

Bottom Headings

SHOTCRETE MIX DESIGNS

Project: Harlan Diversion Contractor: Granmetto/Incisa Date: [illegible]/91

Design strength: 4000psi Mix Design No.: SFG8 Supplier: Mountain construction Concrete Division

Material	Source	Specific Gravity x 62.4
Cement	[illegible]	[illegible] = 3.15 x 62.4
Fly Ash	[illegible]	[illegible] = [illegible] x 62.4
Micro Silica		x 62.4
Sand	[illegible]	[illegible] = 2.66 x 62.4
Stone	[illegible]	[illegible] = 2.72 x 62.4
Steel Fiber	[illegible]	[illegible] = 7.3 x 62.4

Material	Weight per C. Y.	Solid Volume	% Moisture	Actual Weight
Cement	750	3.82		
Fly Ash	100	.70		
Micro Silica	—	—		
Sand	1600	9.64		
Stone	1100	3.48		
Steel Fiber	100	0.22		
Air (6%)	—	1.62		
Water (35gal)	292	4.67		
Total	3942	27.15		

Admixtures	Manufacturer/Type	Test Panel No.
AEA oz./cwt		
WRA oz./cwt		
oz./cwt		
oz./cwt		

Shotcrete Data	

Concrete Temperature: Air Temperature: W/C Ratio:

Percent Coarse Aggregate: Slump: Air Content:

8.7.2 Shotcrete Problems. The fall-out of wet shotcrete from the tunnel crown presented a safety hazard and resulted in much wasted shotcrete. The contractor brought in several consultants in an effort to solve this problem. Changes suggested by representatives of product manufacturers and the American Concrete Institute did not produce significant improvement.

Shotcrete consultant Mr. Neil McAskill of HBT AGRA Limited in Burnaby, British Columbia visited the project to observe the entire shotcrete operation and try to determine the cause of shotcrete fallout. Tests indicated that the initial set was taking as long as one hour and 15 minutes. One of Mr. McAskill's suggestions was to change accelerators. The contractor switched from Accela-Set II Liquid to QSL-100. With QSL-100 the shotcrete began to take it's initial set in 10 to 15 minutes. Shotcrete was applied in two-inch layers, waiting about fifteen minutes between applications. These changes greatly reduced fall-out and produced a smoother finished shotcrete surface.

8.8 Water Occurrance and Drainage Provisions. Groundwater occurrence was limited to small seeps from joints and bedding planes, and to intermittent flows through fractures in response to rainfall. Most of the water encountered in the

tunnels was a by-product of construction activities - dust control sprays on the roadheaders and washing of rock surfaces before shotcrete application. Surface runoff entered the tunnels from the upstream portal area and was allowed to flow to the downstream portals where it was directed to a sediment pond. When necessary to comply with state regulations, water was treated to remove suspended solids before being pumped into Clover Fork.

Water pressure tests conducted during tunnel design showed little or no take in the tunnel zones. No significant groundwater flows were anticipated and none were encountered during construction.

8.9 Instrumentation. The Corps of Engineers installed eight multiple-position borehole extensometers (MPBX's) and an observation well (OW) on Ivy Hill above the tunnels before construction began. The contractor installed single-position borehole extensometers (SPBX's), tape extensometer (TX) anchor points, and load cells. Some of the instruments were grouped in the following arrays, at five locations in the first 1,000 feet of tunneling:

1. Two rock bolt load cells (one in the crown and one in the haunch).
2. Four TX anchor points (one at each side of the tunnel at spring line and two in the haunch). One of these arrays coincided with the location of MPBX-8. TX anchor points were also installed at the other MPBX locations, and at six other selected locations.
3. Six SPBX's, two each in lengths of one foot, five feet, and ten feet (three in the crown and three in the haunch).

Instrument Array Locations

Array	Tunnel	Station	Array	Tunnel	Station
A	1	10+77	J	3	22+11
B	1	13+67	K	3	11+36
C	1	15+98	L	2	26+52
D	2	11+26	M	4	13+82
E	1	18+68	N	4	15+97
F	2	15+33	O	4	19+23
G	1	25+55	P	4	23+96
H	1	9+95	Q	4	27+37
I	3	18+23	R	4	29+05

Arrays A through E were full instrumentation arrays with load cells, SPBX's, and five point TX's. Arrays F through R had 3-point TX's only. Tunnel instrumentation details are included in Appendix I.

8.9.1 Load Cells. Fifty-ton capacity electrical resistance strain gage type load cells, manufactured by Slope Indicator Company, were installed on ten tunnel bolts to

monitor long term performance of the bolt anchorage system and any increases in load which occurred because of volume changes in the rock surrounding the tunnels. Only the fast-set resin bond zone cartridges were used in load cell installations.

Load cells were read immediately after installation, daily for the first 60 days after installation and while tunnel excavation was within 80 feet of the load cell, and weekly thereafter for the duration of all tunnel excavation. Load cell bolts were locked off at loads ranging from about 1½ to 6 kips, the load created by tightening the nut with a pneumatic impact wrench. Tunnel load cells indicated cumulative increases up to about 1½ kips during their monitoring period. Upon completion of tunnel excavation, load cells were removed, the annular space filled with cement grout, and the area covered with shotcrete.

Most of the load cells performed very well for the life project. The major problem was with occasional wet connections which produced erroneously high readings.

8.9.2 Multiple-Position Borehole Extensometers. The Corps of Engineers installed eight multiple-position borehole extensometers, each having five anchor points, to monitor displacement during construction. Installations were as shown on PLATES I-1 and I-2.

The initial readings were made before tunnel excavation began. Reading frequency was daily when tunnel excavation was within 300 feet of the instrument, three times per shift (four times in a 24 hour period) when tunnel excavation was within 50 feet of the instrument, and weekly thereafter. Displacements, measured to the thousandth of an inch, were graphed to illustrate changes from the initial reading. The contractor was required to provide immediate notification if displacements exceeded the following:

Anchor No.	Displacement @100%	Displacement @130%	Displacement @ 160%	Displacement @190%
6	0.247 in.	0.321 in.	0.395 in.	0.469 in.
5	0.217 in.	0.282 in.	0.347 in.	0.412 in.
4	0.177 in.	0.230 in.	0.283 in.	0.336 in.
3	0.125 in.	0.162 in.	0.200 in.	0.237 in.
2	0.090 in.	0.117 in.	0.144 in.	0.171 in.

The MPBX's however, showed very little movement throughout construction, and never exceeded the notification level. Readings generally remained stable as the tunnel headings advanced past them. Displacements ranging from +0.1 to -0.09 inches were indicated. The lowest anchors should have shown the greatest displacements, though this was not always the case. Questionable data is indicated when higher anchors show more displacement than lower ones, and in cases of negative displacement. MPBX graphs are included in Appendix I, PLATES I-12 through I-23. Monitoring of MPBX's was discontinued upon

completion of tunnel excavation. The above ground portions were dismantled in February 1992.

8.9.3 Single-Position Borehole Extensometers. In each array, two anchors were set at one foot, two at five feet, and two at ten feet depths. SPBX's were read immediately after installation, daily for the first 60 days and while excavation was within 80 feet of the instrument, and weekly thereafter for the duration of all tunnel excavation.

The contractor was required to provide immediate notification if displacements exceeded the following:

Anchor Embedded	Displacement @ 100%	Displacement @130%	Displacement @160%	Displacement @190%
1 ft.	0.267 in.	0.347 in.	0.427 in.	0.507 in.
5 ft.	0.217 in.	0.282 in.	0.347 in.	0.412 in.
10 ft.	0.177 in.	0.230 in.	0.283 in.	0.336 in.

Generally the deeper anchors should have shown the greatest displacements, though this was not always true. The SPBX readings ranged from +0.125 to -0.05 inches and never exceeded the notification level. Repeatability of the readings varied by about 0.005 inches. Abrupt changes and negative deflections indicate readings of questionable accuracy. SPBX graphs are included in Appendix I, PLATES I-41 through I-48.

Even simple mechanical instruments are subject to providing questionable and erroneous readings. Review of the instrumentation graphs indicates that the SPBX readings were the most erratic. The fluctuations shown on these graphs probably reflect the degree of accuracy of the depth gauge used to measure these instruments.

8.9.4 Tape Extensometers. Tape extensometers were read immediately after installation, weekly for the first 60 days and while excavation was within 80 feet, and as directed thereafter. Measured TX deflections generally ranged from +.025 to -.02 feet, with no discernable pattern to the changes. Tape extensometer graphs are included in Appendix I, PLATES I-32 through I-40. Tape extensometer anchors planned for installation on centerline in the crown of the tunnels were relocated, to provide clearance for the 60-inch diameter tunnel ventilation line.

8.10 Foundation Mapping and Approval Process. All tunnel surfaces were inspected and mapped by a Corps of Engineers geologist. Preliminary inspections were made immediately after exposure to determine if additional rock bolts and drain holes were needed. A geologist re-inspected and mapped the rock surfaces after they were washed and just prior to shotcrete application. Final foundation approval was given before shotcrete was applied. Mapping was as described by Engineer Technical Letter No. 1110-1-37, "Geologic Mapping of Tunnels

Tunnels.

and Shafts by the Full Periphery Method." Mylar base maps were prepared in advance. Using a scale of one inch equals ten feet, each sheet represents 50 linear feet of tunnel. Tunnel maps are included in Appendix D.

8.11 Possible Future Problems and Recommended Observations. The only anticipated problem is the possibility of shotcrete cracking near the portals. Very little seepage was observed during construction. That which did occur was located along bedding planes and joints near the portal areas. Since these areas are more exposed to outside temperatures, some freezing and cracking of shotcrete could occur.

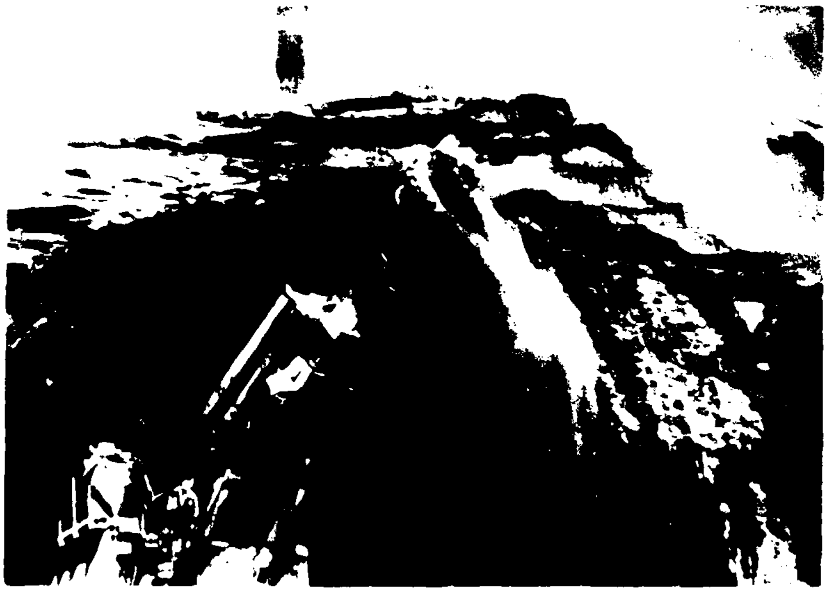
TUNNEL EXCAVATION
METHODS AND DATES

Tunnel No.	Heading	Excavation Method	Station From	Station To	Dates From	Dates To
1	Top	Paurat	9+80	30+39	9-04-90	3-19-91
	Bottom	Paurat	9+80	10+51	4-13-91	4-14-91
		Blasting	10+51	30+39	4-29-91	6-20-91
		Trimming w/Dosco	9+80	30+39	8-16-91	11-21-91
2	Top	Dosco	10+48	10+71	9-04-90	9-10-90
		Dosco	10+71	10+96	9-19-90	9-22-90
		Dosco	10+96	25+38	11-12-90	8-14-91
		Paurat	25+38	30+24	8-15-91	9-20-91
	Bottom	Paurat	10+48	11+75	9-26-91	10-01-91
		Blasting	11+75	30+24	10-02-91	12-02-91
		Trimming w/Dosco	11+75	30+24	11-21-91	2-27-92
3	Top	Dosco	11+18	11+59	9-25-90	10-04-90
		Dosco	11+59	12+20	10-17-90	10-26-90
		Paurat	12+20	14+16	4-02-91	4-13-91
		Paurat	14+16	30+13	4-15-91	8-08-91
	Bottom	Paurat	11+18	11+81	8-12-91	8-13-91
		Blasting	11+81	30+13	8-19-91	9-25-91
		Trimming w/Dosco	11+81	30+13	2-28-92	4-17-92
4	Top	Dosco	11+69	11+91	9-11-90	9-17-90
		Dosco	11+91	12+20	10-05-90	10-16-90
		Dosco	12+20	12+72	10-26-90	11-07-90
		Paurat	12+72	30+05	10-02-91	3-23-92
	Bottom	Paurat	11+69	11+83	3-31-92	3-31-92
		Blasting	11+83	30+05	4-01-92	5-01-92
		Trimming w/Paurat	11+69	30+05	5-04-92	6-26-92

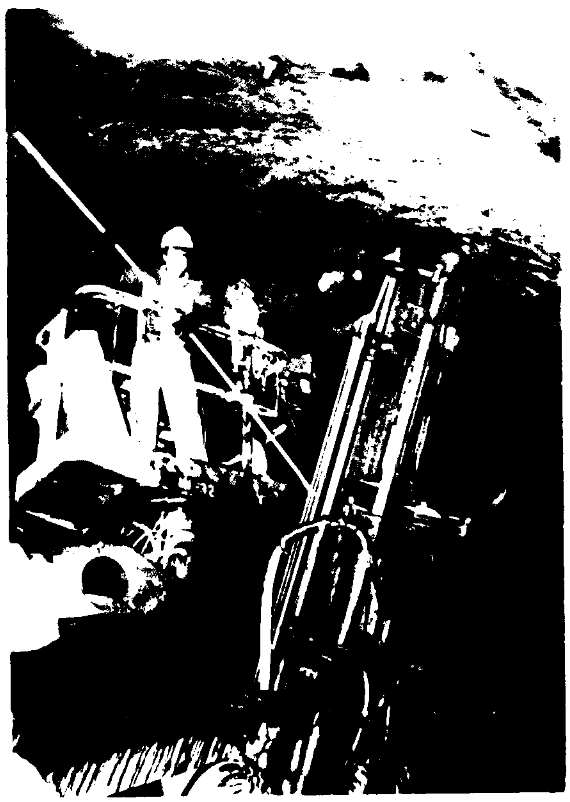
[illegible] ready [illegible] excavation [illegible]
[illegible] August [illegible]

[illegible]
[illegible] September [illegible]

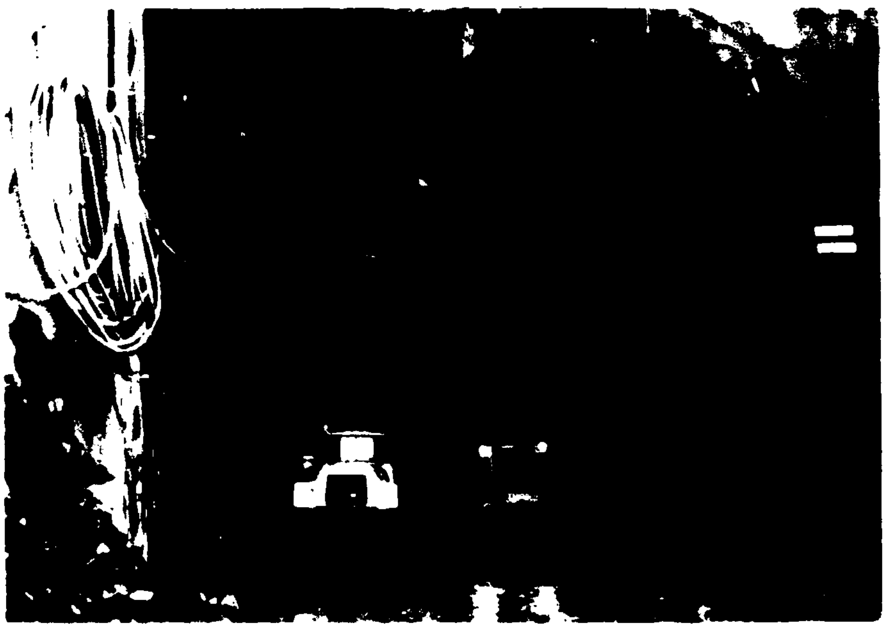
[illegible] gray, very fine grain sandstone beds in
[illegible] 4, station 22+00. February 1992



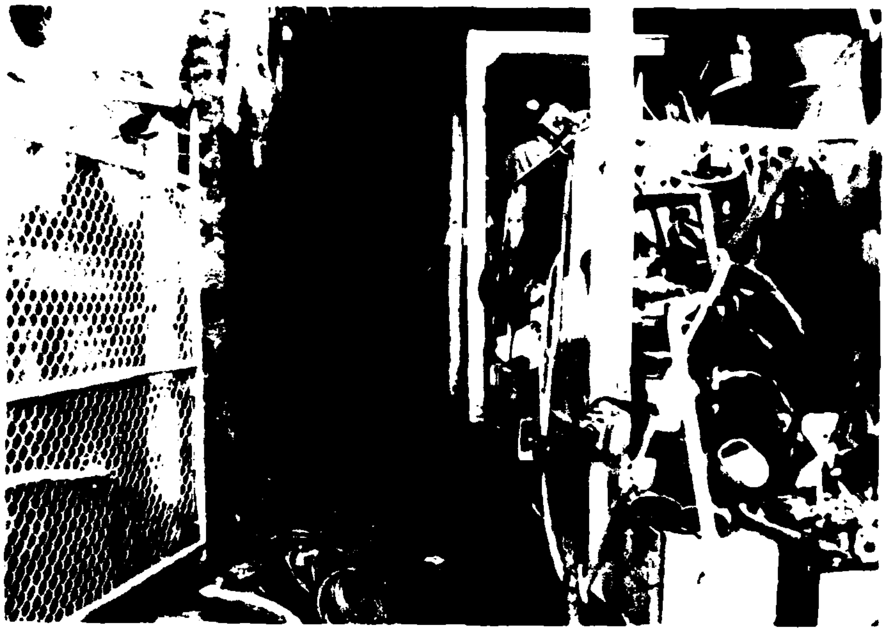
[illegible] cutting tunnel 1 bell mouth
20 March [illegible]



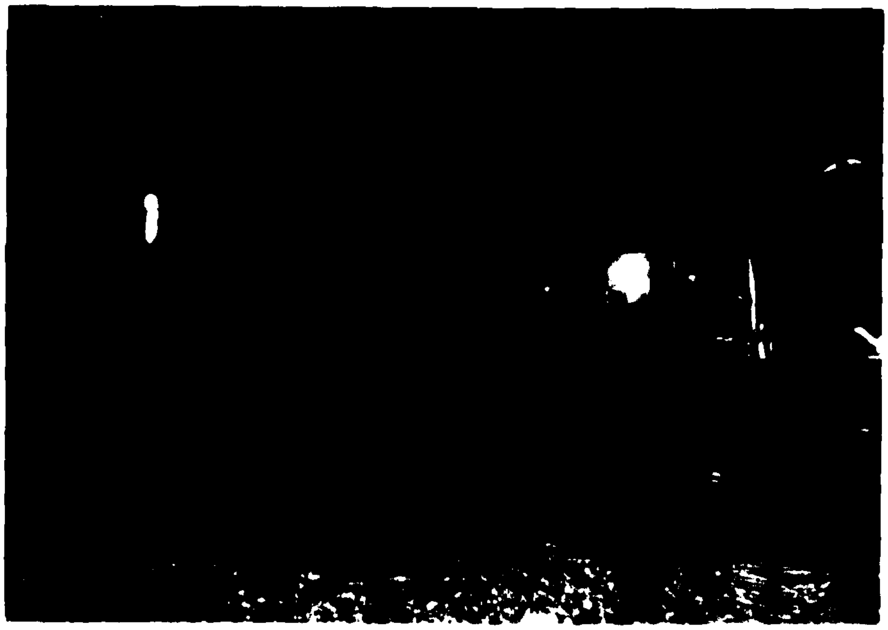
[illegible] pile after blasting in tunnel [illegible], station [illegible]
[illegible] May [illegible]



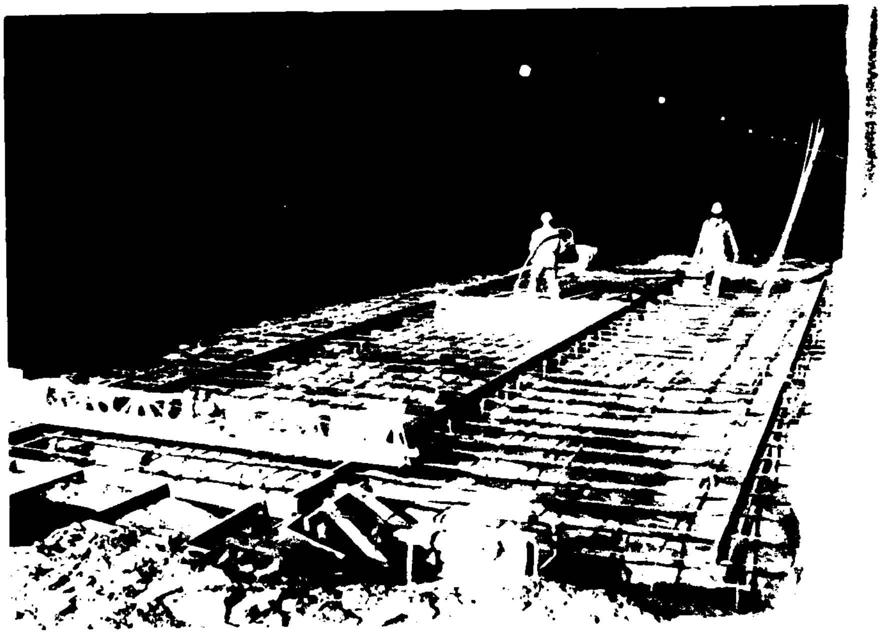
[illegible] loading muck from blast in [illegible]
[illegible] April [illegible]



View from behind Dosco roadheader, preparing to trim bottom heading in tunnel 1. August 199[illegible]



Dosco roadheader trimming left side of tunnel 1.
20 November [illegible]



9. Diversion Structure.

Located immediately adjacent to and downstream of the upstream portals, the diversion structure serves to divert flows of the Clover Fork from the natural river channel into the four tunnels. With a total length of about 710 feet, the structure is comprised of 580 feet of embankment with a slurry trench cutoff along it's upstream toe, 66 feet of concrete floodwall, and a 50-feet-long closure structure at the railroad crossing. Under a contract modification, a sheet pile seepage cut-off installed at the right abutment. This is described in section 9.2.8. Construction of the diversion embankment, slurry trench, floodwall and closure structure are discussed individually in this report.

The diversion structure was completed in two phases. The floodwall, railroad closure structure, and the embankment and slurry trench from station 7+25 to station 4+55 were constructed first, while the tunnels were being excavated. Phase 1 stopped at station 4+55 in order to maintain an eighty feet wide floodway along Clover Fork. Phase 2, from station 4+55 across the river channel, was constructed after Clover Fork had been diverted through the tunnels.

9.1 Embankment. Longitudinally, the crest elevation of the embankment is sloped, from elevation 1211.8 on the right abutment to elevation 1212.1 at the tie-in with the floodwall. With an average foundation elevation of 1182.0, the embankment has an average height of 30 feet. Embankment slopes are 1V:3H for both the upstream and downstream sides, and the crest width is ten feet. The embankment was constructed primarily of material from the tunnel excavation.

The embankment was made more seepage resistant by a covering of 40-mils-thick PolyFlex high density polyethylene geomembrane. Covering this geomembrane is a minimum two-feet-thick layer of fine (minus three-inch) tunnel cuttings and a one-foot-thick layer of topsoil. The geomembrane was anchored at the bottom of the slurry trench on the upstream side, extended up and over the embankment, and was buried in an anchor trench ten feet beyond the downstream toe of the embankment.

9.1.1 Excavation Grades. Specifications required at least one foot of stripping below original ground level in the flood plain, and at least three feet of excavation across the river channel. To remove unsuitable material, an additional 1½ to 4 feet of excavation was required in the flood plain, on the south side of the river.

9.1.2 Engineering Characteristics of Foundation Materials. The major portion of the embankment is founded upon floodplain deposits up to approximately 20 feet thick. The soils are mainly alluvial silts, sands, and gravels. The alluvium typically has a very loose to loose, silty sand

layer immediately below the surface that ranges from 3.0 to 10.4 feet in thickness, with an average thickness of 5.5 feet. Below this silty sand layer the soil grades to a sandy gravel which ranges from 7.0 to 9.7 feet in thickness. Below this gravel layer lies the siltstone bedrock. Preconstruction drive sample investigations recovered an average of 2.1 feet of siltstone before refusal was met. This is indicative of the depth and degree of weathering of the bedrock surface. PLATES E-5 and E-6 present cross-sections through the embankment foundation area, and include boring logs.

During design, permeabilities of the embankment and foundation materials were assumed as shown below:

Material	Horizontal Permeability cm/sec	Vertical Permeability cm/sec
Embankment	1×10^{-1}	1×10^{-2}
Silts and Silty Sands	1×10^{-3}	1×10^{-4}
Gravel	1×10^{-2}	1×10^{-3}

A soil-bentonite slurry trench cutoff, with a specified maximum permeability of 1×10^{-6} cm/second, was installed along the upstream toe of the embankment. Slurry trench construction is discussed in Section 9.2 of this report.

9.1.3 Drainage Provisions. An eight-inch diameter perforated polyethylene pipe was installed along the downstream toe of the embankment, sloping towards the existing channel. Mirafi polypropylene geotextile and Mirafi Miradrain 6000 geocomposite sheets were installed just beneath the impervious geomembrane on the downstream side of the embankment. The geotextile and geocomposite are tied into the downstream toe drain.

9.1.4 Dewatering Requirements. The ground water level was about the same as nearby Clover Fork, elevation 1172.5. This was about six feet below the deepest excavation for foundation preparation and dewatering was not necessary.

9.1.5 Embankment Phase 1 (Station 7+25 to 4+55) - Construction Summary. The Harlan Gas Road was closed on 10 April 1991 to start construction of the first phase of the diversion embankment and associated structures. A water line relocation for the Black Mountain Utility District was completed on 3 May. Topsoil stripping and excavation of unsuitable foundation material began on 18 April. Foundation soils were compacted and about seven feet of embankment fill was placed in building up to the slurry trench working surface, about elevation 1184. Construction of the first

phase of the slurry trench started on 18 October and ended on 18 November 1991. Uninterrupted placement of embankment fill resumed on 15 January and the first phase of the embankment was complete by the end of March 1992.

Two relocated water lines owned by the Black Mountain Utilities District extend beneath the diversion dam in an upstream to downstream direction, adjacent and parallel to the old Harlan Gas Road. Water line locations are shown on Plate E-12. The pipe trench was backfilled with two feet of #8 gravel and tunnel roadheader cuttings. Seepage cutoff was provided by a geomembrane boot installed around the pipes and welded to a surrounding geomembrane liner, and by the soil-bentonite slurry trench located along the upstream toe of the embankment.

Topsoil was stripped using a D8K dozer. The cleaner topsoil was stockpiled nearby for later use on the embankment. The more contaminated material was hauled to the H-2 disposal area. Overexcavation was required to remove a 1½ to 4-feet thick layer of unsuitable organic material and trash across the entire embankment foundation area between Clover Fork and the Harlan Gas Road. This area was reportedly used as a city landfill in the past. After stripping the unsuitable material, the entire surface of the embankment foundation area was compacted by six passes of a 15-ton vibratory roller.

Rock excavated from the tunnels, having a maximum size of 12-inches, was used as fill for construction of the diversion embankment. Shot rock from the bottom heading of tunnel 1 was used for the first lift. Subsequent lifts utilized shot rock from tunnel 1 and roadheader cuttings from tunnels 2 and 3. Rockfill was spread into one-foot layers using a D8K dozer, then compacted by six passes of a 15-ton vibratory roller. Any oversize rock fragments were reduced to minus 12-inches as the material broke down under the leveling and compaction processes. Tunnel cuttings which could not be placed directly on the embankment were stockpiled for later use.

Up to eight feet of rockfill was placed in building up to elevation 1187-1189, the working level for slurry trench construction. The slurry trench working surface was completed in June, 1991. Fill placement was interrupted to allow construction of the first phase of the slurry trench and work on the railroad closure structure.

Uninterrupted placement and compaction of embankment fill resumed on 15 January, 1992 from the north side of the railroad closure structure to station 4+55. It was noted that roadheader cuttings pumped under equipment load if placed too wet, behaving more like soil than rock. The Corps of Engineers tested in-place embankment fill. Assuming a standard density of 167.0 lbs/ft^3 (the density of siltstone),

compaction of about 82% was obtained with six passes of the vibratory roller. Optimum moisture content was about 5%. A test data sheet which indicates densities obtained with varying moisture contents and compactive efforts is included in Appendix E, PLATE E-11.

Moisture was controlled by placing only the drier Paurat roadheader cuttings directly on the embankment. The wetter Dosco cuttings were stockpiled. Rain caused delays in embankment fill placement and compaction.

Placement of fill between the railroad closure structure and embankment station 4+55 continued throughout February. By the end of March 1992, the first section of the diversion embankment had been topped out, except for final filling around the closure structure, and plating with topsoil was in progress. Construction of the remaining section of embankment across Clover Fork awaited completion of the slurry trench which, in turn, was dependent upon diversion of Clover Fork through the tunnels.

9.1.6 Embankment Phase 2 (Station 4+55 to 1+00) - Construction Summary. Clover Fork was diverted through the tunnels on 21 September, 1992. The remainder of the embankment foundation was stripped, and up to six feet of weathered siltstone was removed in the Clover Fork channel, down to elevation 1162-1163. Embankment fill was then placed up to elevation 1186 to provide a working surface for completion of the slurry trench. Phase 2 of the slurry trench was constructed in October 1992. Embankment fill placement resumed immediately thereafter and was completed in December 1992.

9.1.7 Instrumentation. No instrumentation was installed in the diversion structure.

9.1.8 Possible Future Problems and Recommended Observations. Erosion of topsoil and fill could expose the geomembrane, leading to its deterioration. Vehicular traffic on the embankment would aggravate embankment erosion problems.

9.2 Slurry Trench. To provide a barrier to foundation seepage, a slurry trench cutoff was constructed along the upstream toe of the embankment. The trench extends downward from the base of the embankment and is embedded two feet into the siltstone bedrock. The trench has vertical sidewalls and is a minimum of 36-inches wide. An impervious geomembrane liner was installed on the upstream side and the trench filled with soil-bentonite backfill. The total depth of the slurry trench is about twenty feet.

The slurry trench was constructed in two phases. Phase I began at station 7+25 near the railroad tracks and extended toward the river to station 4+55. Phase 1 stopped at station

4+55 in order to maintain an eighty-feet-wide floodway along Clover Fork. Phase 2, from station 4+55 across the river channel to station 1+65 was constructed after Clover Fork had been diverted through the tunnels.

9.2.1 Construction Equipment - Phase 1. The first section of the trench was excavated by a track mounted Link Belt LS-5800 backhoe equipped with a 46-inch or a 36-inch wide bucket which was capable of excavating both the overburden and bedrock. This backhoe was also used to lower the geomembrane sheets into the trench. A Caterpillar D-8 dozer excavated backfill material from it's borrow site and a Caterpillar 950B rubber tired endloader hauled it from the borrow site to the backfill mixing area. A Dresser TD-15C dozer mixed the soil-bentonite backfill and pushed it into the trench.

9.2.2 Construction Equipment - Phase 2. A Komatsu PC300LC track mounted backhoe was used to excavate the second phase of the trench. This backhoe was smaller and less effective than the Link Belt LS-5800 used during Phase 1. A Komatsu D63E-1 dozer mixed the soil-bentonite backfill and pushed it into the trench.

9.2.3 Excavation Grades - Design and As-Built. The design minimum elevation of the slurry trench working surface was 1184 across the Clover Fork channel, and 1186 elsewhere, as shown on PLATE E-1. The slurry trench was constructed below a work surface ranging from elevation 1187.1 to 1184.8. PLATE E-2 shows as-built elevations for the entire slurry trench.

The slurry trench was constructed as designed, with the following exceptions:

1) The geomembrane liner was installed on the upstream side of the trench.

2) A sheet pile seepage cutoff was added in the right abutment area, from station 1+80 to station 0+15. See Section 9.2.8 for details of this modification.

9.2.4 Slurry. To support the walls of the trench during excavation, the trench was kept filled with a water-bentonite slurry. Slurry was mixed in a slurry batch plant to produce a colloidal suspension of bentonite in water. The specifications required that water losses not be greater than 20 cubic centimeters as determined by API Test 13A, Section 5. This criteria was used to determine whether water softening agents were needed in the slurry mixture. Based upon passing test results, water softeners were not used.

9.2.5 Geomembrane Liner. A 30-mils-thick Polyflex high density polyethylene geomembrane liner was installed the full depth of the slurry trench. To seal the geomembrane around the relocated water pipes a geomembrane "boot" was

placed around the pipes, secured with a band clamp. The base of the boot was welded to overlapping sheets of geomembrane placed flat against the trench wall. Geomembrane installation is described in Sections 9.2.7 and 9.2.8.

9.2.6 Backfill. Specifications for the soil-bentonite backfill required an average permeability of no greater than 1×10^{-6} centimeters per second, and a bentonite content of at least four per cent. As-built permeabilities were much lower than required, ranging from 3.1×10^{-9} to 96.1×10^{-9} centimeters per second.

The contractor's permeability testing was done by Soil Testing Engineers, Inc. of Baton Rouge, Louisiana. The Corps of Engineers also tested samples at it's Ohio River Division laboratory. Backfill permeability test results are summarized below.

Trench Station	Permeability	Tested By
6+70	9.4×10^{-9}	Contractor
5+90	7.8×10^{-9}	Contractor
4+85	4.3×10^{-9}	Contractor
6+80 - 5+80	15.1×10^{-9}	CE
6+70	3.1×10^{-9}	CE
5+90	96.1×10^{-9}	CE
4+85	16.8×10^{-9}	CE

Backfill was prepared by mixing suitable material excavated from the trench (estimated to be 20% of the total excavated quantity), borrow material (silty sand), bentonite powder, and a slurry composed of bentonite powder and Harlan city water. A three to six-inch slump was specified. For the first phase the contractor elected to use a six-inch slump. For the second phase a three-inch slump was used with improved results. The lower slump allowed greater control over the movement of the advancing backfill toe, and it's position relative to the geomembrane sheets.

9.2.6.1 Backfill Borrow Site - Phase 1. Several backhoe pits were dug in the alluvium upstream of the embankment and adjacent to Clover Fork to locate the best borrow site for slurry trench backfill material. Gradation test results indicated that, although on the fine side of the specification requirement, suitable backfill material was available. This silty sand occurred in a four feet thickness near the ground surface. Over-size rock and debris were removed by hand. Gradation results are included in Appendix E, PLATES E-9 and E-10.

9.2.6.2 Backfill Borrow Site - Phase 2. Eight- hundred cubic yards of material, which had been excavated from beneath the old Highway 38, was stockpiled for use in completing the slurry trench backfill.

9.2.7 Slurry Trench, Phase 1 (Station 7+25 to 4+55) - Construction Summary. Phase 1 trench excavation began on 18 October and backfilling was completed on 18 November 1991. The subcontractor had originally estimated about two weeks, but repair of damaged water lines extended construction time. Excavation began alongside the railroad embankment and progressed toward the river. This provided the excavator more solid ground on which to maneuver, and prevented interference with railroad traffic.

The LinkBelt LS-5800 backhoe used a standard 46-inch wide bucket to excavate the trench. A surveyor's level was set up to provide vertical control. Stakes, offset well away from the work area, were used for horizontal control. After breaking a bucket tooth on 25 October, the 46-inch wide bucket was replaced with a 36-inch wide bucket. The replacement bucket was also equipped with ripping teeth mounted on the outside, and proved more efficient at excavating in rock.

Prior to the placement of geomembrane and eventual backfilling, the subcontractor sounded the trench to verify that it was clear and free of sediment. When sounding revealed that sediment had accumulated, the backhoe was used to clean the trench before backfilling began.

Geomembrane placement began on 29 October. Placing the geomembrane sheets on the upstream side of the trench allowed the exposed flap of geomembrane to lie clear of the soil-bentonite backfill mixing area which was located on the downstream side of the trench. Specially notched sheets of geomembrane were placed around water lines which crossed the trench. Placement of the material was difficult, as the geomembrane tended to be buoyant in the slurry. The bottom edge had to be forced into place despite re-bar woven into the geomembrane bottom to act as a sinker. Once backfilling began, the six-inch slump backfill was expected to assume a 1V:8H slope in the trench. This was later measured and was found to range from about 1V:8H to 1V:10H. For this reason over-lapping geomembrane sheets had to be installed well ahead of the backfill operations. Backfilling began at a 1V:1H lead-off trench near the railroad tracks. As the advancing backfill flowed past the geomembrane sheets, the bottom was dragged laterally along with it. Upper edges pulled loose from the top of the trench, and the geomembrane sagged under the weight of the backfill material. Sheets of geomembrane were staked on their upper edge, and additional sheets placed to cover the gaps which opened as the original sheets were dragged apart. It was apparent that a better method of geomembrane installation would have to be devised.

Backfilling of the freshly-excavated trench was completed to station 4+55 on 2 November. The backfill was excavated to expose the water lines where they crossed through the trench. The water lines were exposed and found to have been damaged

by the backhoe during excavation of the slurry trench. The water lines were repaired and the trench subcontractor began installation of the pipe boot. A backing sheet of geomembrane was placed under the pipes, slit at the pipe locations, and pulled up and around the water lines. The bottom of this backing sheet of geomembrane was driven to rock using angle iron attached to the bottom edge of the material with welded sockets, and steel pipes inserted into the sockets as push rods. A backhoe then pushed the geomembrane sheet to the bottom of the trench. The geomembrane boot was welded to this backing sheet. Around the pipes, the geomembrane was gathered and secured with two hose-type clamps on each pipe. Fresh backfill material was mixed, and the trench completed on 16 November. A layer of filter fabric was placed to cover the exposed top of slurry trench backfill. Fill placement resumed, covering the slurry trench on 25 November.

9.2.8 Slurry Trench, Phase 2 (Station 1+70 to 4+55) - Construction Summary. In June 1992, the contractor drilled four air-track holes to determine depth to bedrock at the northwest end of the trench, in the right abutment. Indications were that the top of rock surface was much lower than estimated. A Corps of Engineers crew drilled three additional SPT/core holes which confirmed the preliminary findings. Drill logs for these three holes are included on PLATE E-7.

The contract was modified to extend the foundation seepage cutoff further into the right abutment. A sheet pile cutoff was added, extending from station 1+70 to station 0+15, the centerline of the relocated Highway 38. After the slurry trench was completed, the piling cutoff was extended an additional 10 feet into the slurry trench, to station 1+80. See PLATES E-2 and E-3.

Phase 2 slurry trench excavation began on 22 October and backfilling was completed by 31 October 1992. A much improved method was used to install the geomembrane liner. Geomembrane sheets were attached to rigid frames constructed of four-inch pipes and six-inch steel I-beams. Frames and attached geomembrane sheets were installed in 30 feet high and 35 feet wide sections. Four frames were used, each frame installed to lap about four feet behind the previously placed frame. When backfill reached a depth of ten feet along a section, a frame was pulled, leaving the geomembrane sheet in the trench.

Excavation for the two feet embedment into rock was slow, about 40 linear feet per day. The upper six feet of weathered rock had been removed before fill placement began. The rock which remained was difficult to excavate with a backhoe.

9.3 Floodwall and Closure Structure. Floodwalls and a railroad closure structure were constructed at the left abutment of the diversion embankment. These structures are founded on HP 12 x 74 piles driven through artificial fill and alluvium, to refusal in the siltstone bedrock. The closure structure has a single-leaf swing gate with a span of 30 feet and a height of 14.25 feet. The floodwall consists of a 12-feet long section of T-wall on each side of the closure structure and 42 feet of I-wall. A sheet pile seepage cutoff was driven to refusal in bedrock beneath these structures.

9.3.1 Construction Summary. An alternate access road to nearby homes was constructed on the landward side of the railroad right-of-way in December 1991. This replaced the existing road which was blocked by the railroad closure structure. H-piles and sheet piles were driven on both sides of and under the railroad tracks in January 1992. The railroad was out of service for about ten hours while sections of the track were removed on 22 January. Sheet piles 42 and 43 failed to go to refusal on the first attempt. Both these piles were pulled and were successfully driven to refusal on the second attempt. During pile driving operations a seismograph was set up ten feet from the corner of a nearby church, 75 feet from the pile driver. The highest recorded reading was 0.04 inches per second.

Pile driving hammer for sheet piling:

Model MKT-9B3
Ram Wt. 1600 lbs.
Stroke Rated-17 inch
Energy Rated 8750 Ft/lbs.
Speed Rated 145
Air Pressure 100

Pile driving hammer for H-piling:

Model Vulcan 506
Ram Wt. 6500 lbs.
Stroke Rated-48 inch
Energy Rated 26,000 Ft/lbs.
Speed Rated 52
Air Pressure 120

Closure structure footings were placed in February 1992. General details of the closure structure and floodwalls are shown on Plate F-2. Pile driving records are included on PLATE F-3.

Dozer pushing soil-bentonite backfill into 1V:1H
lead-off trench. 31 October 1991

Backfilling phase 1 of the slurry trench.
View looking toward right abutment.
31 October 1991

Slurry trench, phase 2. Trench ex[illegible] and backfill mixing in progress. [illegible]

[illegible]

10. Highway 72 Bridge.

At the downstream portal area, Highway 72 was re-routed over a 450-feet-long bridge which spans Clover Fork as it exits the tunnels.

10.1 Abutments. Construction of the bridge abutments started in October 1990 and was completed in May 1991. The bridge abutments are supported by 14-inch structural steel H-piles driven through the overburden to refusal in bedrock. All piles were fitted with cast steel driving points furnished by Versabite Foundation Accessories of Matthews, North Carolina. Piles were driven to refusal, which was defined as "when measurable penetration under five blows of the approved hammer and system is one-quarter inch or less and where the pile tip is in bedrock and the installation is approved by the Contracting Officer."

London Bridge Company used a 60-ton Link-Belt 118 crane with a fixed lead system. The pile driver was a Vulcan model #506 single acting hammer with 6500 pound ram weight, 690 pound anvil weight, and a 48-inch stroke for 26,000 foot-pounds of energy. The hammer speed was 52 blows per minute with air pressure of 120 PSI. A 750-pound Vulcan pile driving cap and a 12-inch diameter by 2½-inch aluminum and Micarta cushion block were used.

Abutment 1 piles were driven in October 1990. Pile lengths ranged from about 16 to 30 feet. Tip elevations ranged from about 1147 to 1160, which is consistent with preconstruction exploratory boring top of rock data.

Abutment 2 pile driving began on 23 October 1990. Piles 11 and 43 hit an obstacle approximately 18 feet below the surface. The piles were skewed in opposite directions, suggesting that the obstruction lay between the piles. The angle of skew was within permissible limits, and no corrective action was necessary. Piles ranged from about 19 to 24 feet in length. Tip elevations ranged from about 1142 to 1146. Pile records are provided on PLATE G-2.

10.2 Piers.

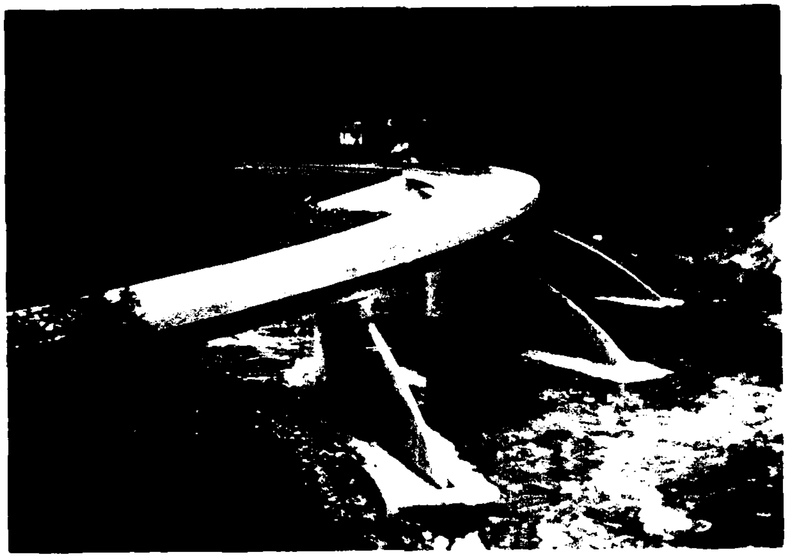
10.2.1 Pier 1. Excavation for pier 1 began on 21 November 1990. A D-8 dozer equipped with a single-tooth ripper was used to make the initial cut into rock. The trench was then trimmed to final dimensions using a backhoe and jackhammers. Rock samples were collected from the pier foundations and tested for slake durability, with test results ranging from 96.3% to 97.9%. Three five-feet-deep test holes confirmed rock competency. Contract modification 37 provided for a design change which was recommended by the bridge designer. The footing was expanded in size so that concrete would be in contact with the sides of the excavated trench.

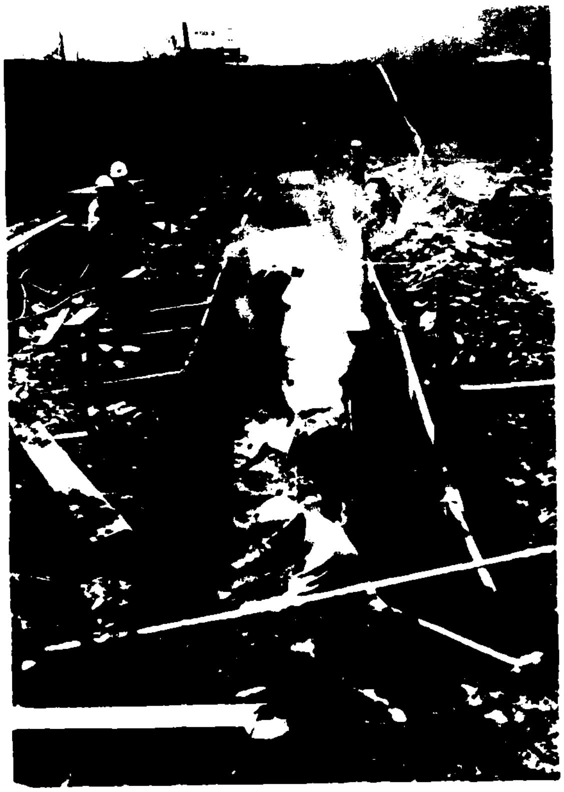
10.2.2 Pier 2. A dike was built around the pier 2 excavation to control surface water. Excavation began on 29 January 1991 using a backhoe and jackhammers. The dozer and ripper were not used in order to reduce overbreakage similar to that which occurred on the pier 1 footing excavation. Slake-durability testing on rock sampled below pier 2 footing indicated an SDI of 97.95%. Three test holes drilled five feet into rock below the footing confirmed rock competency. The pier 2 footing was placed on 13 February.

10.2.3 Pier 3. Excavation of pier 3 foundation began on 9 February 1991. As on pier 2, only a backhoe and jackhammers were used. The pier footing was separated from the main channel of Clover Fork by an earthen berm. Seepage through the berm entered the excavation and required continuous pumping. Concrete was completed on 22 March.

Pre-stressed concrete I-beams for the bridge were placed during May 1991. Ivy Hill Road was re-opened to traffic on 23 August, permitting traffic to enter Harlan from the north side of Ivy Hill. The Highway 72 bridge was opened to traffic on 2 October 1991.

Embankment. 71





11. Highway 38 and Bridge.

11.1 Excavation Grades - Design and As-Built. In developing the 1V:1H slope at the top of the road cut, hard sandstone was encountered higher than expected in some areas. Where this occurred the slopes were changed from a 1V:1H dozer cut to a 2V:1H presplit cut. This necessitated the addition of an extra bench at the upper part of the slope so that the lower slopes could be constructed according to design. These changes increased excavation quantities.

Jointing runs approximately parallel to the road cut and in some areas the presplit blasts broke back to expose joint faces. Since there was no provision for rock bolting the road cut, and in many cases the rock was too fractured to be bolted effectively, loose rock was removed behind the design line. This also increased excavation quantities.

11.2 Overburden Excavation. Utility lines were relocated around the work area from October 1989 through January 1990. Overburden excavation began in March 1990. Excavation of the 1V:1H slope in overburden began in March and was essentially complete by the end of July 1990. Additional excavation is described in Section 11.2.2.

11.2.1 Methods and Equipment. Overburden was excavated using a Caterpillar D-8 dozer. A Caterpillar 977L endloader loaded material onto Euclid R50 dump trucks which hauled it to the H-2 disposal area.

11.2.2 Construction Summary, Problems, and Treatment. Between stations 67+50 and 69+00 organic material unsuitable for the road subgrade was overexcavated. The area was backfilled with rock from the upstream portal excavation.

In January 1991, overburden in a hollow at station 56+50 to 57+00 slid to the bottom of the excavated cut. Headward erosion reached to within eight feet of the project property boundary, and left remaining overburden on the slope excessively steep and prone to further sliding. Laying the slope back away from the cut would result in encroachment outside the project property boundary. The Pineville real estate office made arrangements to purchase this additional property. Excavation of slide material and laying back of the slope was completed in March 1991.

By April 1991 road cuts were excavated to grade on either side of the tunnel portals. Between stations 52+50 and 55+00, four to nine feet of unsuitable organic overburden material was overexcavated. The area was backfilled with shot rock, from the upstream portal excavation. A surface leveling course of tunnel roadheader cuttings was placed to complete the backfilling. Organic material, unsuitable for road subgrade, was also removed between stations 70+50 to 71+50. The overexcavated area, 15 feet wide and four feet

deep, was backfilled with tunnel cuttings. Other unsuitable material was removed by a cut 20 feet wide and three feet deep from station 68+75 to 70+00. Several large boulders were removed from the subgrade near abutment 1 in August 1991.

11.2.3 Disposition of Excavated Materials. Overburden from the highway 38 excavation was placed in the H-2 disposal area.

11.3 Rock Excavation. Blasting for the highway 38 relocation began near station 66+00 in March 1990.

11.3.1 Methods and Equipment. Presplit blasting methods were similar to those used at the downstream portal and at the upstream portal above elevation 1230. Holes were 3-inches in diameter, on 36-inch centers, and up to 30 feet deep. ⅞-inch diameter Detagel was initiated with electric blasting caps. In developing the cut-slopes, presplit lines ran approximately parallel to the existing ground surface only a short distance away. Firing the presplit line in a separate operation before the production blast disturbed the remaining rock to the extent that it was difficult to drill the production blast holes. If production holes were drilled before the presplit shot, holes were cut off and could not be loaded. For these reasons, the presplit and production blasts were usually fired in one operation, separated by millisecond delays.

11.3.2 Construction Problems and Treatment. Blasting broke back to expose joint planes where they intersected design slopes. Fractured rock and detached blocks were removed, leaving natural joint faces to form the finished slope in these areas. This backbreak added to overruns in surface excavation quantities.

11.3.3 Disposition of Excavated Material. Rock from the highway 38 excavation was placed in the H-2 disposal area.

11.4 Rock Reinforcement. Reinforcement of the slopes was not required by the contract. Some rock bolts were installed as needed and paid at unit prices. Five 25-feet-long rock dowels were installed, from station 69+60 to 70+00 elevation 1330 to secure an overhanging sandstone block. A nearby utility pole and construction limits prevented removal of the entire block. Six rock bolts, three 10-feet long and three 15-feet long, were installed between stations 50+00 and 50+50 for support of a small overhang.

11.5 Bridge Foundation - Caisson Construction. Proposed caisson locations for the Highway 38 bridge were core drilled during March 1991. NX core holes were drilled through the approximate center of each caisson to a target depth of five feet below the proposed bottom. Augers

advanced the holes through overburden to top of rock where coring began. Cores were logged, photographed, and discarded. In some holes, a sample of core was taken for compressive strength testing. Test results are included in Section 4.2.4, "Investigations During Construction." Drilling logs are included in Appendix H, PLATES H-3 and H-4.

Drilling results on abutment 1 essentially confirmed the depth of the overburden/rock contact indicated in the plans. Abutment 2 results, however, revealed the overburden/rock contact in two holes to be substantially (14 to 18 feet) deeper than expected. Rock Quality Designations were also lower on several abutment 2 cores. Since some change in caisson design would probably be necessary, core holes were deepened so that at least 20 feet of rock was recovered, to a depth five feet below the anticipated base. Core drilling was completed on 26 March, 1991, and the results forwarded to the bridge designer.

The bridge abutment caissons were re-designed, with the most significant changes being:

- --Enlarge caissons A2-2 and A2-3 to 60-inches in diameter.
- --Add one 60-inch diameter caisson along the A2-1 to A2-4 row and change spacing of caissons in that row.
- --Enlarge caisson A1-1 to 60-inches in diameter.
- --Increase rock embedment length to a minimum of 15 feet for all 48-inch diameter caissons and 20 feet for 60-inch diameter caissons.

The revised drilled shaft notes, schedule, and layout are enclosed in Appendix H, PLATE H-2.

A Hughes LDH-70 drill rig arrived on site on 18 June and caisson hole drilling started on 24 June. Rock augering was slowed by occasional bands and beds up to 1½ feet thick, of very-fine-grained sandstone, sometimes descibed as coarse-grained siltstone. Drilling rates slowed to fractions of an inch per hour with very high auger tooth consumption. When this very hard rock was encountered, a 1350 pound drop hammer was used. The general procedure was to drop the hammer eight to ten times. Although not advancing the hole measurably, this would slightly fracture and roughen the rock surface, allowing the rock auger or core barrel to cut through it. A coring bit was sometimes used instead of the rock auger to provide additional cutting action around the margins of the hole. Once the very hard beds were penetrated, rock augering continued at normal rates of approximately one foot per hour.

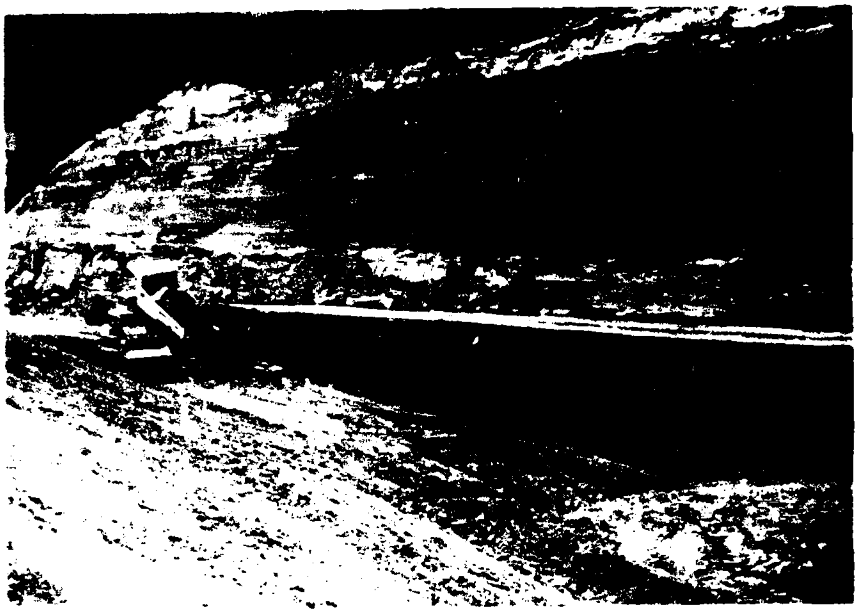
All completed caisson holes were proof tested by drilling a five-feet-deep jackhammer hole in the bottom. Proof testing of hole A2-5 revealed a void approximately one foot below the bottom. The caisson hole was deepened an additional 3.9 feet and re-inspected. A fracture, open 1.6 feet and oriented

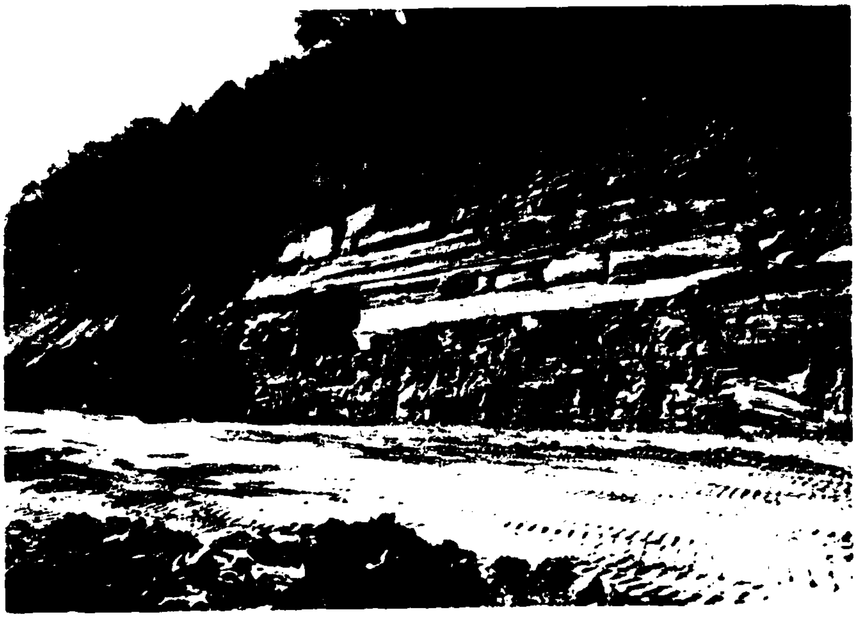
N20°E, 80°NW, was observed in the side of the hole. The wall rock and hole bottom beneath the fracture appeared to be competent with no evidence of further voids. Additional proof testing indicated good rock for a depth of five more feet. The open fracture was plugged to limit concrete flow to six inches inside the feature, and non-reinforced concrete was placed up to the original design bottom. Reinforcing steel was then placed in the hole, and concrete placed following normal procedures.

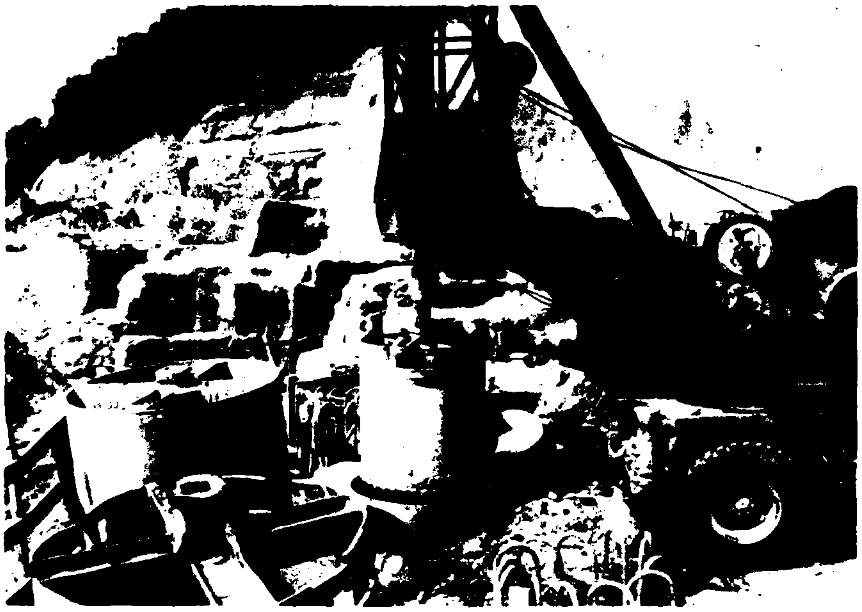
Caisson hole A2-4 was started on 15 August. Fill material around the collar of the hole caved-in and forced temporary abandonment of the drilling. Additional fill was placed and compacted as well as possible in the confined area. A 20-feet-long section of temporary casing was installed and drilling resumed. Caisson construction was completed on 11 September, when concrete for caissons A2-4 and A2-6 was placed.

Completed caisson holes were checked for verticality, and all were within the specified tolerances which were (1) the top no more than three-inches from centerline location, and (2) a maximum deviation, from top to bottom, of 1.5% of caisson height.

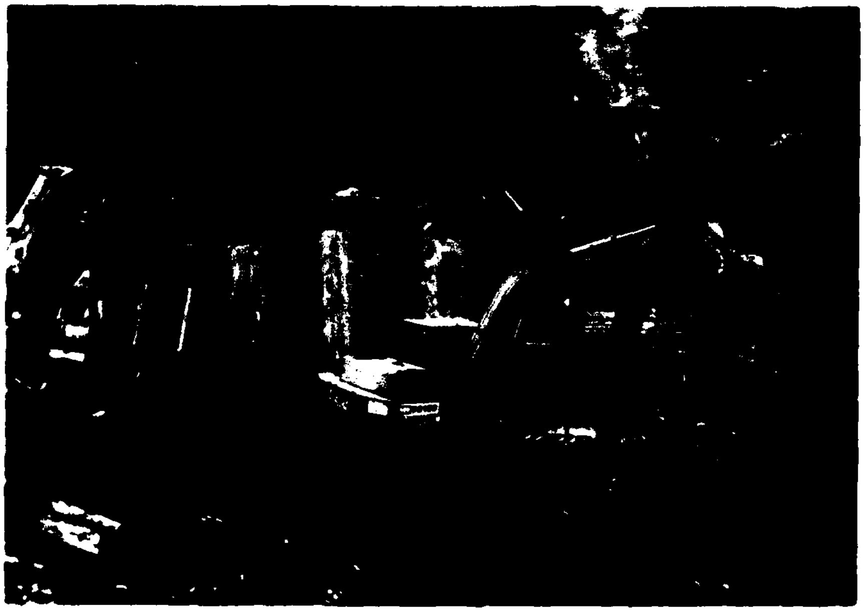
All caisson holes except A1-6 were mapped peripherally prior to placement of reinforcing steel and concrete. That hole was proof tested, and the jackhammer operator reported good rock at the base of the caisson, and no visible fractures in the wall rock. Caisson hole maps are included in Appendix H, PLATES H-5 through H-19.







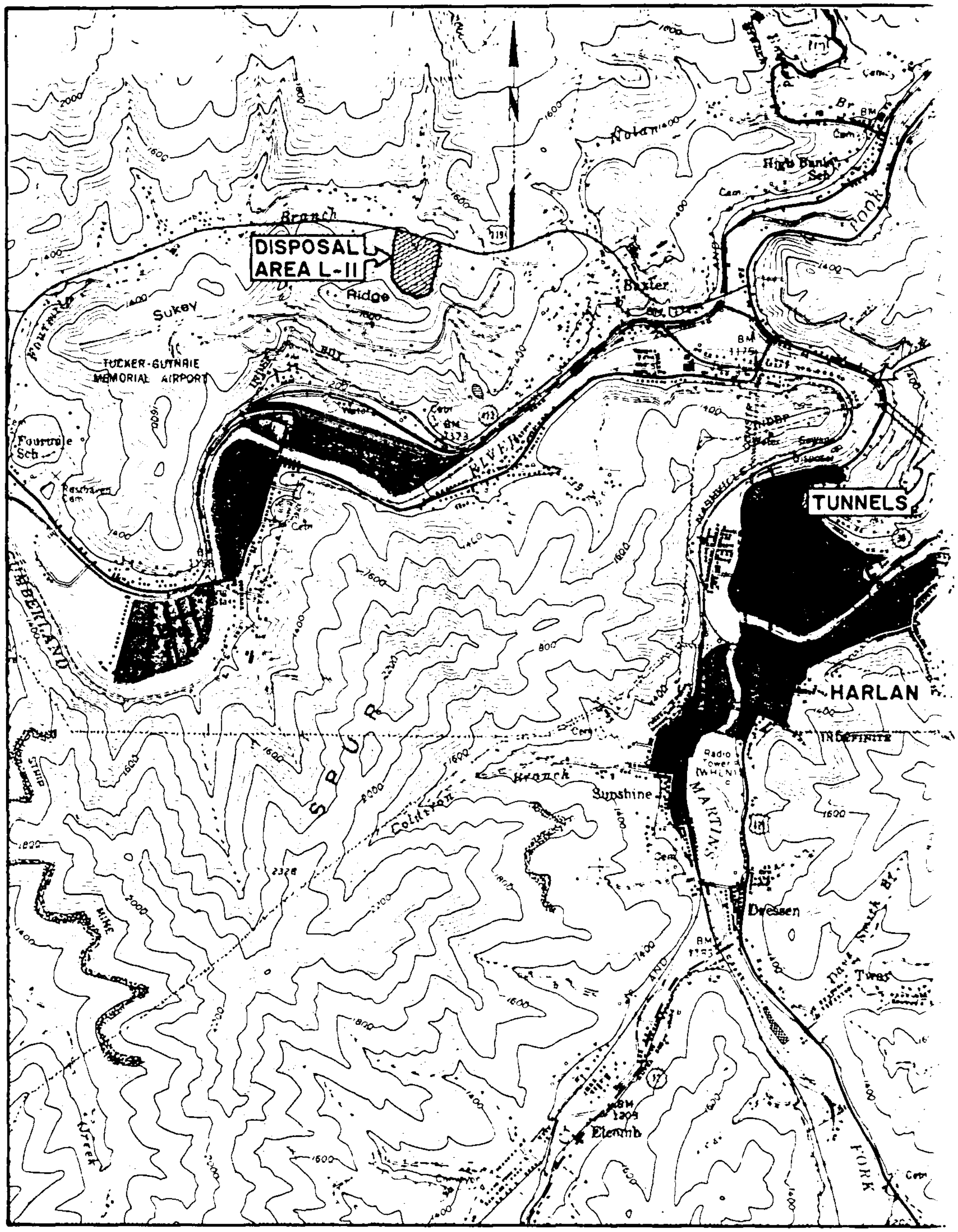
[illegible] drill rig with [illegible] bit, [illegible]
[illegible] August [illegible]



[illegible] used to excavate rock alongside the
[illegible] caissons for wing wall embedment. View
[illegible] looking downstream. January [illegible]

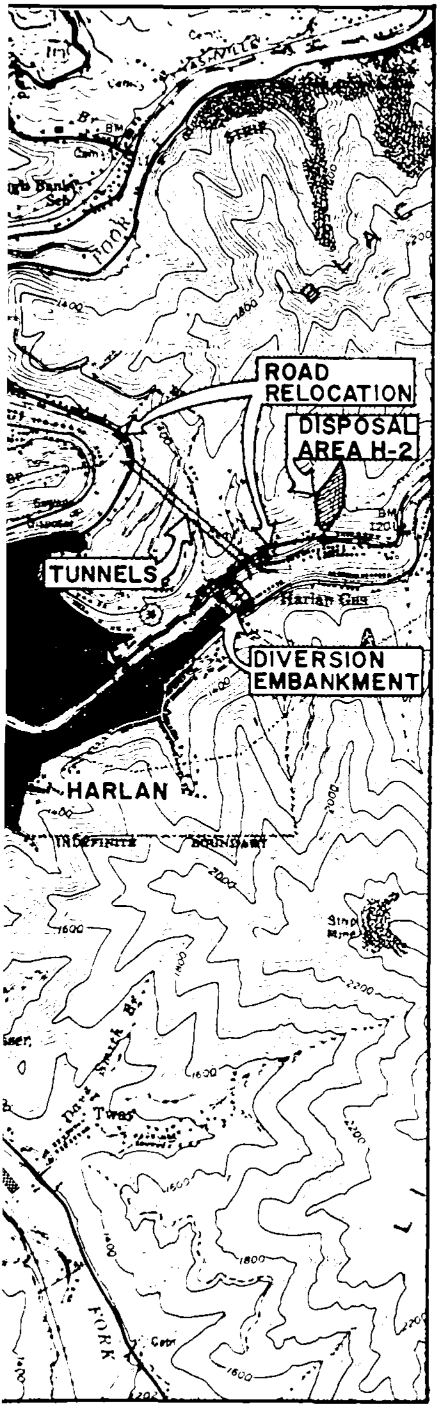
Appendix A - General

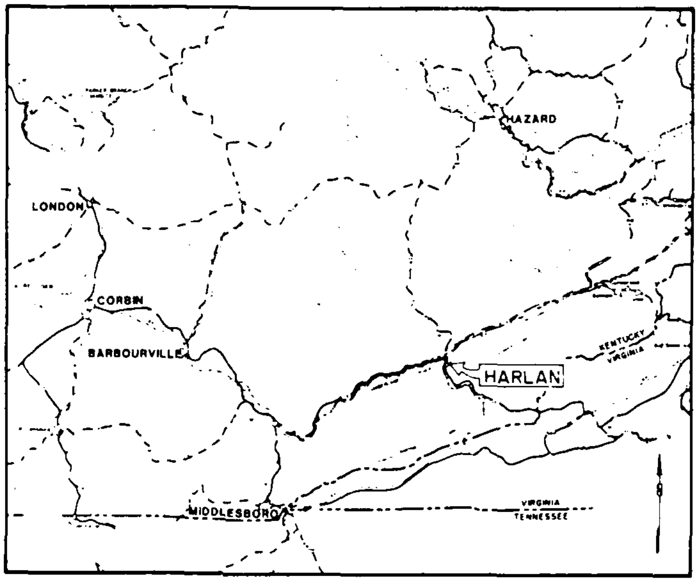
Plate No.	Drawing No.	Description
A-1	Q1A-64/1	Project Location Map
A-2	Q1A-4/382	Boring Legend
A-3 thru 5	------	Geologic Descriptions



PROJECT LOCATION MAP

5 4 D C B A





VICINITY MAP
NOT TO SCALE

Revisions	Date	Descriptions	By	Checked

Graphic Scale

US ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

US Army Corps of Engineers

UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY

PROJECT LOCATION MAP

Designed by:

Drawn by:

Checked by:

Approved by:

Date:

Sheet _ of _

Scale:

Drawing Number QIA-64/1

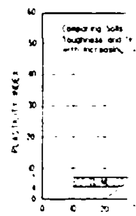
Record Drawing as constructed dated

UNIFIED SOIL CLASSIFICATION

(Including Identification and Description)

Major Divisions		Group Symbols	Typical Names	Field Identification Procedures (Excluding particles larger than 3 inches and basing fractions on estimated weights)	Information Required for Describing Soils
1	2	3	4	5	6
Coarse-grained Soils. More than half of material is larger than No. 200 sieve size. The No. 200 sieve size is about the smallest particle visible to the naked eye.	Gravels. More than half of coarse fraction is larger than No. 4 sieve size. (For visual classification, the 1/4 in. size may be used as equivalent to the No. 4 sieve size.) Clean Gravels (Little or no fines)	GW	Well graded gravels, gravel-sand mixtures, little or no fines.	Wide range in grain sizes and substantial amounts of all intermediate particle sizes.	For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics.
		GP	Poorly graded gravels, gravel-sand mixtures, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.	
	Gravels with Fines (Appreciable amount of fines)	GM	Silty gravels, gravel-sand-silt mixtures.	Nonplastic fines or fines with low plasticity (for identification procedures see ML below).	Give typical name; indicate approximate percentages of sand and gravel, max. size; angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbol in parentheses.
		GC	Clayey gravels, gravel-sand-clay mixtures.	Plastic fines (for identification procedures see CL below).	
	Sands. More than half of coarse fraction is smaller than No. 4 sieve size. Clean Sands (Little or no fines)	SW	Well graded sands, gravelly sands, little or no fines.	Wide range in grain size and substantial amounts of all intermediate particle sizes.	Example:
		SP	Poorly graded sands, gravelly sands, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.	Silty sand, gravelly; about 20% hard, angular gravel particles 1/2-inch maximum size; rounded and subangular sand grains coarse to fine; about 15% nonplastic fines with low dry strength; well compacted and moist in place; alluvial sand; (SM).
	Sands with Fines (Appreciable amount of fines)	SM	Silty sands, sand-silt mixtures.	Nonplastic fines or fines with low plasticity (for identification procedures see ML below).	
		SC	Clayey sands, sand-clay mixtures.	Plastic fines (for identification procedures see CL below).	
				Identification Procedures on Fraction Smaller than No. 40 Sieve Size — Dry Strength (Crushing characteristics) / Dilatancy (Reaction to shaking) / Toughness (Consistency near PL)	
Fine-grained Soils. More than half of material is smaller than No. 200 sieve size.	Silts and Clays. Liquid limit less than 50	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.	None to slight / Quick to slow / None	Give typical name; indicate degree and character of plasticity, amount and maximum size of coarse grains, color in wet condition, odor if any, local or geologic name, and other pertinent descriptive information, and symbol in parentheses.
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.	Medium to high / None to very slow / Medium	
		OL	Organic silts and organic silty clays of low plasticity.	Slight to medium / Slow / Slight	
	Silts and Clays. Liquid limit greater than 50	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.	Slight to medium / Slow to none / Slight to medium	For undisturbed soils add information on structure, stratification, consistency in undisturbed and remolded states, moisture and drainage condition.
		CH	Inorganic clays of high plasticity, fat clays.	High to very high / None / High	Example:
		OH	Organic clays of medium to high plasticity, organic silts.	Medium to high / None to very slow / Slight to medium	Clayey silt, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; (ML).
Highly Organic Soils		Pt	Peat and other highly organic soils.	Readily identified by color, odor, spongy feel and frequently by fibrous texture.	

Laboratory [illegible] Use grain size curve in identifying the fractions as given under field identification. Determine percentages of gravel and sand from grain size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size) coarse grained soils are classified as follows: Less than 5% GW, GP, SW, SP. More than 12% GM, GC, SM, SC. 5% to 12% Borderline cases requiring use of dual symbols. Atterberg [illegible] Atterberg [illegible] with PI [illegible] Atterberg [illegible] Atterberg [illegible] with PI [illegible] For lab [illegible]



(1) Boundary classifications. Soils possessing characteristics of two groups are designated by combinations of group symbols. For example GW-GC, well graded gravel-sand mixture with clay binder. (2) All sieve sizes on this chart are U.S. standard.

FIELD IDENTIFICATION PROCEDURES FOR FINE-GRAINED SOILS OR FRACTIONS

These procedures are to be performed on the minus No. 40 sieve size particles, approximately 1/64 in. For field classification purposes, screening is not intended, simply remove by hand the coarse particles that interfere with the tests.

DILATANCY (Reaction to shaking)

After removing particles larger than No. 40 sieve size, prepare a pat of moist soil with a volume of about one-half cubic inch. Add enough water if necessary to make the soil soft but not sticky.

Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times. A positive reaction consists of the appearance of water on the surface of the pat which changes to a livery consistency and becomes glossy. When the sample is squeezed between the fingers, the water and gloss disappear from the surface, the pat stiffens, and finally it cracks or crumbles. The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil.

Very fine clean sands give the quickest and most distinct reaction whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour, show a moderately quick reaction.

DRY STRENGTH (Crushing characteristics)

After removing particles larger than No. 40 sieve size, mold a pat of soil to the consistency of putty, adding water if necessary. Allow the pat to dry completely by oven, sun, or air drying, and then test its strength by breaking and crumbling between the fingers. This strength is a measure of the character and quantity of the colloidal fraction contained in the soil. The dry strength increases with increasing plasticity.

High dry strength is characteristic for clays of the CH group. A typical inorganic silt possesses only very slight dry strength. Silty fine sands and silts have about the same slight dry strength, but can be distinguished by the feel when powdering the dried specimen. Fine sand feels gritty whereas a typical silt has the smooth feel of flour.

TOUGHNESS (Consistency near plastic limit)

After removing particles larger than the No. [illegible] inch cube in size, is molded to the consist[illegible] and if sticky, the specimen should be spre[illegible] moisture by evaporation. Then the specimen [illegible] between the palms into a thread about [illegible] and rolled repeatedly. During the manipulat[illegible] and the specimen stiffens, finally loses its [illegible] is reached.

After the thread crumbles, the pieces shoul[illegible] continued until the lump crumbles.

The tougher the thread near the plastic lim[illegible] the more potent is the colloidal clay frac[illegible] plastic limit and quick loss of coherence of [illegible] inorganic clay of low plasticity, or materials [illegible] which occur below the A-line.

Highly organic clays have a very weak and spongy [illegible]

Adapted by Corps of Engineers and Bureau of Reclamation, January 1952.

LEGEND FOR BORING TYPE SHOWN ON EXPLORATION PLANS

LETTER	SYMBOL	DESCRIPTION
DC		Standard Penetration & Cored
[illegible]		Standard Penetration
		[illegible] Sample
A		Auger Hole
		[illegible] Hole
		[illegible] Hole
D [illegible]		[illegible] Penetration or Core Hole with Piezometer Installation

LEGEND FOR LOGS OF BORINGS AND SUBSURFACE PROFILES AND SECTIONS

HOLE NUMBER AND TYPE — DC-49
SURFACE ELEVATION — 985.[illegible]
[illegible] SAMPLES
SAMPLED [illegible] CLASSIFICATION [illegible]
STANDARD PENETRATION RESISTANCE [illegible]
[illegible]
ELEVATION AND DATE WATER [illegible] OBSERVED
[illegible]

Laboratory Classification Criteria

$C_u = \frac{D_{60}}{D_{10}}$ Greater than 6

$C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3

Not meeting all gradation requirements for GW

Atterberg limits below "A" line or PI less than 4 | Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols.

Atterberg limits above "A" line with PI greater than 7

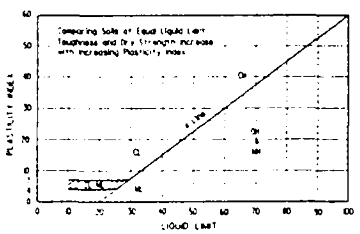
$C_u = \frac{D_{60}}{D_{10}}$ Greater than 4

$C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3

Not meeting all gradation requirements for SW

Atterberg limits below "A" line or PI less than 4 | Limits plotting in hatched zone with PI between 4 and 7 are borderline cases requiring use of dual symbols.

Atterberg limits above "A" line with PI greater than 7



PLASTICITY CHART

For laboratory classification of fine-grained soils

ABBREVIATIONS

@	at	drv	drive	LL	liquid limit	scat	scattered
accum	accumulated	DWR	drillwater retained	* ln	lense	sd	sand
AH	ahead	el	elevation	lo	loose	sdy	sandy
alt	alternating	est	estimate,-ed	ls	limestone	sh	shale
ang	angular	excl	excluding	lt	light	shy	shaly
approx	approximate, -mately	extr	extremely	med	medium	sl	silt
argl	argillaceous	f	fine, finely	mic	micaceous	sls	siltstone
bbl	barrel	fe	iron	min	mineralized, -ization	sly	silty
bdd	bedded, bedding	fld	filled	mod	moderate, moderately	sl	slight, slightly
bdr	bedrock	fm	formation	mot	mottling, mottled	slcs	siliceous
bifur	bifurcating	fos	fossil, fossiliferous	mss	massive	* slick	slickenside
BK	back	* frac	fracture	mst	moist	sml	small
bky	blocky	* frag	fragment	* mtl	material	smpl	sample
* bl	black	frl	friable	mtx	matrix	sft	soft
bld	boulder	fsl	fissile	* nod	nodule	soln	solution, -tioned, -tioning
BOH	bottom of hole	gen	generally	NR	no recovery	SPT	std. penetration test
br	brown	glau	glauconite, -itic	num	numerous	ss	sandstone
brec	brecciated	gr	gray	ob	overburden (unclassified)	st	stain, -ed, -ing
brk	broken	gra	grain, grained	occ	occasional, -ally	stf	stiff
c	coarse	grad	gradational	ool	oolite, oolitic	* strg	stringer
cal	calcite	grn	green	op	open, opened	* styl	stylolite
calc	calcareous	grt	grout	org	organic	stylc	stylolitic
carb	carbonaceous	gvl	gravel, gravelly	part	partially	sur	surface
* cav	cavity	gyp	gypsum	* pbl	pebble	tt	tight
* cbl	cobble	h/a	high angle	petro	petroleum, petroliferous	TR	top of rock
CD	corrected depth	hd	hard	PI	plasticity index	tr	trace
cem	cement	hem	hematite	* pit	pit, pitted, pitting	UL	unaccountable loss
CH	core in hole	hld	healed	PL	plastic limit	unacct	unaccountable
cht	chert	hor	horizontal	pl	plastic	var	variable
circl	circulation	imbdd	imbedded	pla	platy	v	very
cl	clay	incl	including	* pln	plane	vert	vertical
cly	clayey	intbdd	interbed, interbedded	pwdr	powder, powdered	vgy	vuggy
cmtd	cemented	intlam	interlaminated	prob	probable, probably	w/	with
col	columnar	irr	irregular, irregularly	pt	paper-thin	wea	weathered
conc	concrete	* jt	joint	PT	pressure test	wht	white
* congl	conglomerate	l/a	low angle	* ptg	parting	WL	water level
crm	crumbly	lam	lamina, -ae, -ated	qtz	quartz	WT	water table
d	dense	LC	lost core	rec	recovered	x-bdd	cross-bedded
dis	disseminated	LDW	lost drillwater	REF	refusal	xl	crystal
dk	dark	lea	leached	rk	rock	xln	crystalline
dmp	damp	lg	large	rnd	round	yel	yellow
dol	dolomite, dolomitic	lig	lignitic	RQD	rock quality designation		
drl	drilling	lim	limonite	sat	saturated		

* When using as the plural form add "s"

TERMS FOR THICKNESS OF BEDDING

Parting	< 0.02'
Band	0.02' - 0.2'
Thin Bed	0.2' - 0.5'
Medium Bed	0.5' - 1.0'
Thick Bed	1.0' - 2.0'
Massive	> 2.0'

TERMS FOR HARDNESS OF BEDROCK

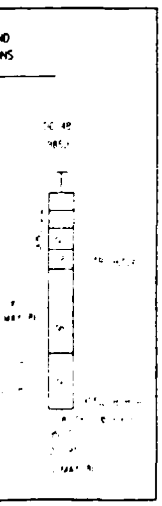
SCALE OF HARDNESS	DESCRIPTION
Very soft or plastic	Can be indented easily with thumb
Soft	Can be scratched with fingernail
Moderately hard	Can be scratched easily with knife; cannot be scratched with fingernail
Hard	Difficult to scratch with knife
Very hard	Cannot be scratched with knife

GENERAL NOTES

1. A BLOW COUNT OF HIGHER THAN 50 BLOWS PER HALF FOOT IS NORMALLY DEFINED AS REFUSAL FOR STANDARD PENETRATION HOLES. FOR ALL OTHER HOLES DRILLED THROUGH OVERBURDEN, REFUSAL IS DEFINED AS THE POINT BEYOND WHICH FURTHER PENETRATION WAS IMPRACTICABLE WITH THE EXPLORATION METHOD USED.
2. WATER ELEVATIONS INDICATED ( ) IN CORE (C), DENISON (U), DRIVE SAMPLED (D), AUGER (A), AND WASHBORINGS (WB) MAY HAVE BEEN INFLUENCED BY TRAPPED DRILLING FLUID OR AN INSUFFICENT PASSAGE OF TIME TO PERMIT BORING TO REFLECT ACTUAL GROUND WATER ELEVATION.
3. GROUNDWATER LEVELS WILL VARY IN ACCORDANCE WITH RAINFALL AND STREAM STAGES. THEREFORE ACTUAL LEVEL OF GROUNDWATER ON ANY DATE OTHER THAN THAT SHOWN ON THE LOGS MUST BE DETERMINED BY SEPARATE OBSERVATIONS. WATER LEVEL READINGS WERE NOT TAKEN ON EVERY HOLE FOR VARIOUS REASONS. THE ABSENCE OF A READING DOES NOT INDICATE THE ABSENCE OF GROUNDWATER.
4. WHEREVER THE METHOD OF EXPLORATION PRECLUDED THE POSSIBILITY OF RECOVERING SAMPLES ABOVE ROCK, SUITABLE FOR EXAMINATION OR TESTS, THE MATERIAL IS DENOTED AS OVERBURDEN.
5. SOME OF THE EXPLORATORY BORINGS ARE PROJECTED ON THE SOIL AND ROCK PROFILES. FOR DISTANCES, SEE PLANS OF EXPLORATION.
6. ALL ELEVATIONS ARE IN FEET AND REFER TO NATIONAL GEODETIC VERTICAL DATUM (NGVD).
7. RQD IS A MEASURE OF THE ROCK QUALITY. ALL LENGTHS OF CORE RECOVERED OVER 4 INCHES IN LENGTH ARE ADDED THEN DIVIDED BY THE TOTAL LENGTH OF CORE WHICH SHOULD HAVE BEEN RECOVERED AND EXPRESSED AS A PERCENTAGE.
8. ADDITIONAL GEOLOGIC STANDARDS ARE INCLUDED ON PLATES A-3 THRU A-5.

GENERAL BEDROCK DESCRIPTION

HANCE FORMATION SILTSTONE: Thick bedded to massive, moderately hard to soft, argillaceous to shaly, unweathered to highly weathered, variably micaceous and carbonaceous, gray, with occasional zones of hard, silty, very fine grained sandstone.



Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN COUNTY, KENTUCKY
DIVERSION TUNNELS

BORING LEGEND

Drawn By: AG	
Checked By: PP	
Approved By:	
Drawing Number	Q1A-4382

Standard Descriptions and Descriptive Criteria for Rock

Hardness

H1	Very Soft	Can be deformed by hand
H2	Soft	Can be scratched by fingernail
H3	Moderately Hard	Can be scratched easily with a knife
H4	Hard	Can be scratched with difficulty with a knife
H5	Very Hard	Cannot be scratched with a knife

Weathering

W1	Unweathered	No evidence of any mechanical or chemical alteration
W2	Slightly Weathered	Slight discoloration on surface, slight alteration along discontinuities, less than 10% of the rock volume is altered, strength is substantially unaffected
W3	Moderately Weathered	Discoloring is evident, surface is pitted and altered with alteration penetrating well below rock surfaces, 10% to 50% of the rock is altered, strength is noticeably less than fresh rock
W4	Highly Weathered	Entire mass is discolored, alteration nearly complete, some pockets of slightly weathered rock noticeable, some minerals leached away, retains only a fraction of original strength

Bedding

B1	Massive	Greater than 2 ft.
B2	Thick Bedded	1 to 2 ft.
B3	Medium Bedded	0.5 to 1 ft.
B4	Thin Bedded	0.2 to 0.5 ft.
	Band	0.02 to 0.2 ft.
	Parting	Less than 0.02 ft.

Void Conditions

Pore (porous)	Less than .003 ft. (1/32 in.)
Pit (pitted)	.003 to .02 ft. (1/32 to 1/4 in.)
Vug (vuggy)	.02 to .33 ft. (1/4 to 4 in.)
Cavity	Greater than 4 in.

Standard Descriptions and Descriptive Criteria for Discontinuities

Fracture Spacing

SP1	Extremely widely spaced....	Greater than 10 ft.
SP2	Very widely spaced.........	3 to 10 ft.
SP3	Widely spaced..............	1 to 3 ft.
SP4	Moderately spaced..........	0.3 to 1 ft.
SP5	Closely spaced.............	0.1 to 0.3 ft.
SP6	Very closely spaced........	Less than 0.1 ft.

Fracture Continuity

C1	Very low continuity.........	Less than 3 ft.
C2	Low continuity..............	3 to 10 ft.
C3	Moderate continuity.........	10 to 30 ft.
C4	High continuity.............	30 to 100 ft.
C5	Very high continuity........	Greater than 100 ft.

Fracture Openness

O0	Tight..................	No visible separation
O1	Slightly open..........	Less than .003 ft. (1/32 in.)
O2	Moderately open........	.003 to .01 ft. (1/32 to 1/8 in.)
O3	Open...................	.01 to .03 ft. (1/8 to 3/8 in.)
O4	Moderately wide........	.03 ft. (3/8 in.) to 0.1 ft.
O5	Wide...................	Greater than 0.1 ft., actual opening recorded

Fracture Filling Thickness

T0	Clean..............	No film or coating
T1	Very thin..........	Less than .003 ft. (1.32 in.)
T2	Moderately thin....	.003 to .01 ft. (1/32 to 1/8 in.)
T3	Thin...............	.01 to .03 ft. (1/8 to 3/8 in.)
T4	Moderately thick...	.03 ft. (3/8 in.) to 0.1 ft.
T5	Thick..............	Greater than 0.1 ft., actual thickness recorded

Fracture Surface (Roughness)

R1	Stepped................	Near normal steps and ridges occur on fracture surfaces
R2	Rough..................	Large, angular asperities can be seen
R3	Moderately rough.......	Asperities are clearly visible and fracture surface feels abrasive
R4	Slightly rough.........	Small asperities on the fracture surface are visible and can be felt
R5	Smooth.................	No asperities, smooth to the touch
R6	Polished...............	Extremely smooth and shiny

Standard Descriptions and Descriptive Criteria For Discontinuities

Fracture Healing

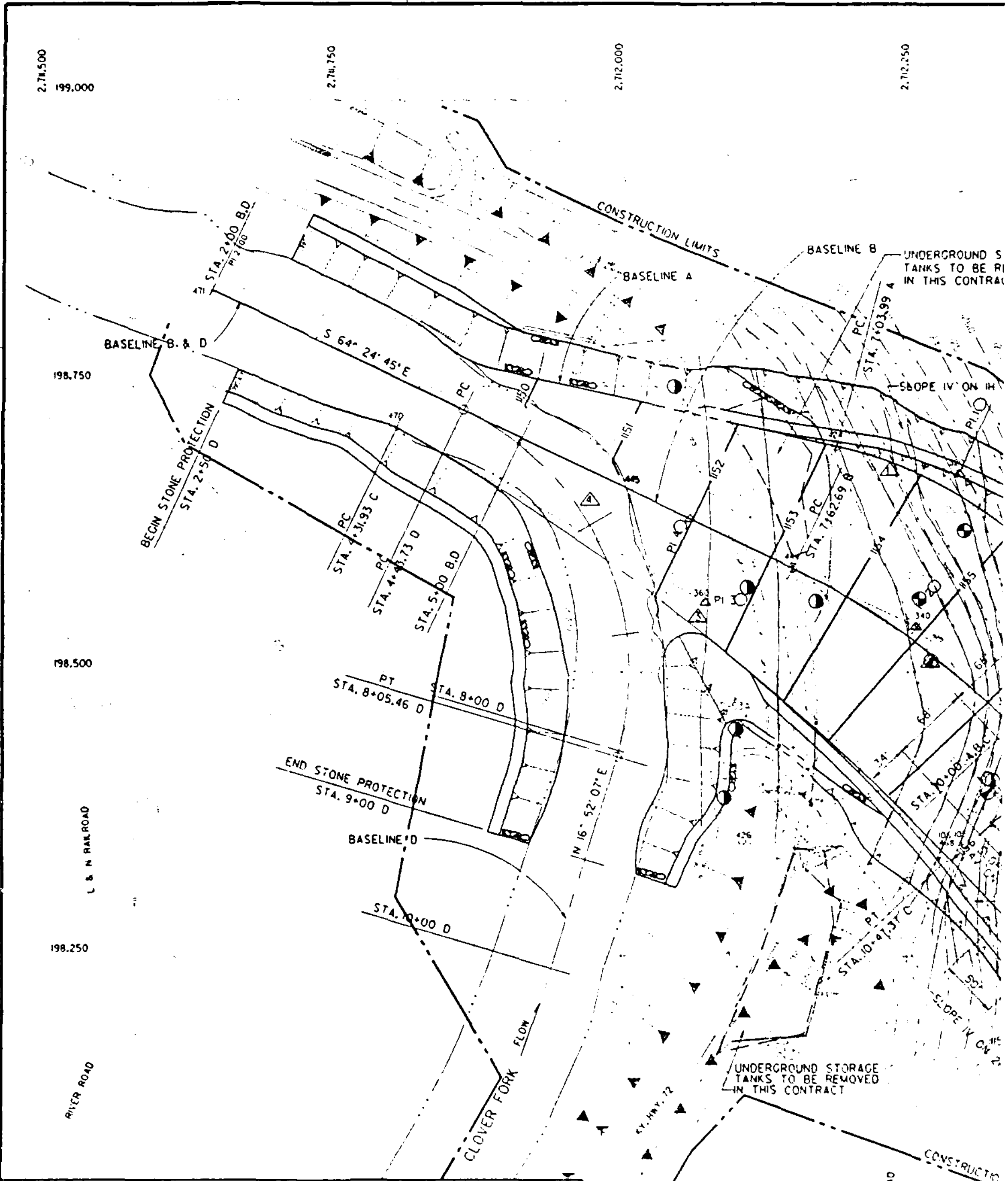
HL1	Totally healed.......	Fracture is completely healed or recemented
HL2	Moderately healed....	Greater than 50 percent of fractured material, fracture surfaces, or filling is healed or recemented
HL3	Partly healed........	Less than 50 percent of fractured material, filling, or fracture surface is healed or recemented
HL4	Not healed...........	Fracture surface, fracture zone, or filling is not healed or recemented

Fracture Moisture Conditions

M1............	The fracture is dry. It is tight or filling (where present) is of sufficient density or composition to impede water flow. Water flow along the fracture does not appear possible.
M2............	The fracture is dry with no evidence of previous water flow. Water flow appears possible.
M3............	The fracture is dry but shows evidence of water flow such as staining, leaching, and vegetation.
M4............	The fracture filling (where present) is damp, but no free water is present.
M5............	The fracture shows seepage. It is wet with occasional drops of water.
M6............	The fracture emits a continuous flow (estimate flow rate).

Appendix B - Downstream Portal

Plate No.	Drawing No.	Description
B-1	Q1A-64/61.3	General Plan
B-2	Q1A-64/39.1	Boring Plan
B-3	Q1A-64/40.1	Geologic Section I-I
B-4	Q1A-64/41.1	Geologic Section J-J
B-5	Q1A-64/42.1	Geologic Section K-K
B-6	Q1A-64/43.1	Geologic Section L-L
B-7	Q1A-64/44.1	Geologic Section M-M
B-8	Q1A-4/383	Excavation Sections
B-9	Q1A-4/384	Section Location Plan
B-10	Q1A-4/385	Excavation Sections
B-11	Q1A-64/60.3	Rock Slope Treatment
B-12	Q1A-64/69.2	Rock Slope Treatment
B-13	Q1A-64/70.2	Rock Slope Treatment
B-14	-------	Added Rock Reinforcement
B-15	-------	Added Rock Reinforcement
B-16	Q1A-4/386	Geologic Map
B-17	Q1A-4/387	Geologic Map, T-4 Portal
B-18	Q1A-4/388	Geologic Map, T-3 Portal
B-19	Q1A-4/389	Geologic Map, T-2 Portal
B-20	Q1A-4/390	Geologic Map, T-1 Portal



CURVE DATA

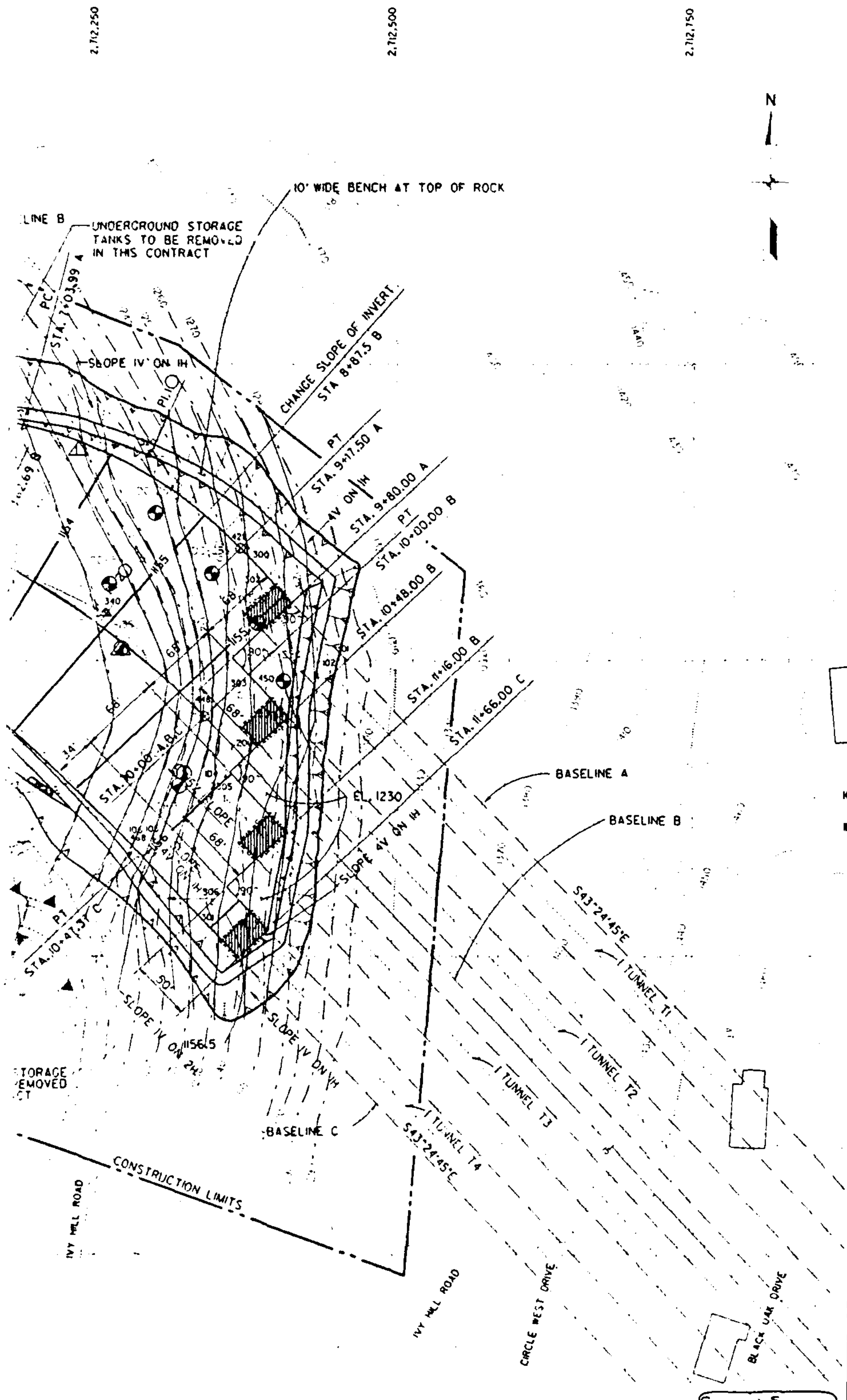
CURVE 1	CURVE 2	CURVE 3	CURVE 4
BASELINE A	BASELINE B	BASELINE C	BASELINE D
PI 5 STA. 9+13.99 A	PI 2 STA. 8+82.69 B	PI 6 STA. 7+41.93 C	PI 4 STA. 6+62.61 D
N 198,674.34	N 198,539.83	N 198,561.62	N 198,534.94
E 2,712,293.85	E 2,712,257.23	E 2,712,072.85	E 2,712,058.73
△ 34°-00'-00"	△ 21°-00'-00"	△ 17°-00'-00"	△ 81°-16'-53"
D 15.92°	D 8.85°	D 2.76°	D 22.47°
L 213.51 FT.	L 237.31 FT.	L 615.44 FT.	L 361.73 FT.
T 110.00 FT.	T 120.00 FT.	T 310.00 FT.	T 218.88 FT.
R 359.79 FT.	R 647.46 FT.	R 2074.26 FT.	R 255.00 FT.

PLAN

SCALE: 1" = 50'

5

4



PLAN

SCALE: 1" = 50'

NOTES

1. FOR GENERAL PLAN OF PROJECT, SEE DWG. NO. 64/2.
2. FOR BORINGS IN AREA OF DOWNSTREAM PORTAL, SEE DWG. NO. 64/39.
3. FOR CROSS SECTIONS ALONG RIGHT BANK (BASELINE C) SEE DWG. NO. 64/62.
4. FOR CROSS SECTIONS ALONG LEFT BANK (BASELINE A) SEE DWG. NO. 64/63 & /64.
5. FOR CROSS SECTIONS ALONG BACKWALL AT TUNNEL EXIT. SEE DWG. NO. 64/65.
6. FOR CROSS SECTIONS OF STREAMBANK PROTECTION IN EXISTING CLOVER FORK CHANNEL. SEE DWG. NO'S. 64/66, /67, & /68.
7. FOR DETAILS OF SLOPE TREATMENT. SEE DWG. NO'S. 64/69 & /70.
8. FOR PLANS OF RELOCATED HIGHWAY 72, SEE SEPARATE FOLIO.
9. FOR INSTRUMENTATION IN AREA OF DOWNSTREAM PORTAL. SEE DWG. NO. 64/79.
10. ALL SLOPES TO BE DEVELOPED PERPENDICULAR TO THE BASE OF THE APPLICABLE CUTS.
11. ALL CUT SLOPES IV ON IH OR STEEPER ADJACENT TO PORTALS SHALL BE SHOTCRETED.

TYPE I STONE SPLASH PADS WITH SLUSH GROUT TYPICAL 4 TUNNELS

Revisions	Date	Description	By	Checked
.3	11-24-93	REVISED AS CONSTRUCTED	S.B.D	
.2	6-30-89	ADDED SLOPE DATA, CONSTRUCTION LIMITS,		
		STORAGE TANK AREAS, AND NOTE 11.	E.P.D.	J.L.S.
.1	5-31-89	CONFORMING TO REVIEW COMMENTS	L.L.	P.E.B.

50' 0 50'

Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

Designed By: P.E.R.

Drawn By: W. LIGON FAULKENBERRY

Checked By:

Approved By: CHIEF, GEOTECHNICAL BRANCH

UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION
GENERAL PLAN
DOWNSTREAM PORTAL

Date: FEB. 1989

Sheet of

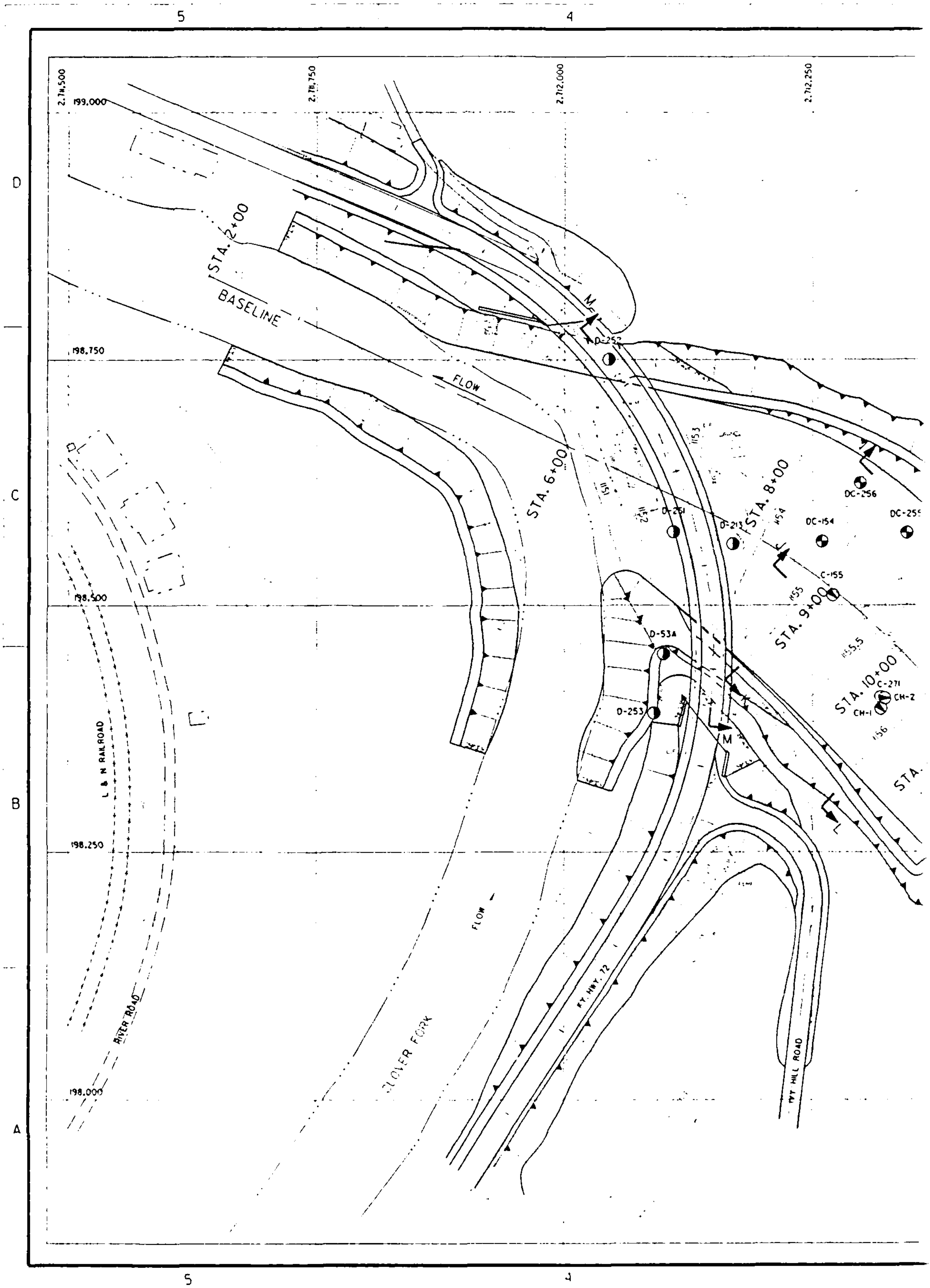
Scale: 1" = 50'

Drawing Number 01A-64/61.3

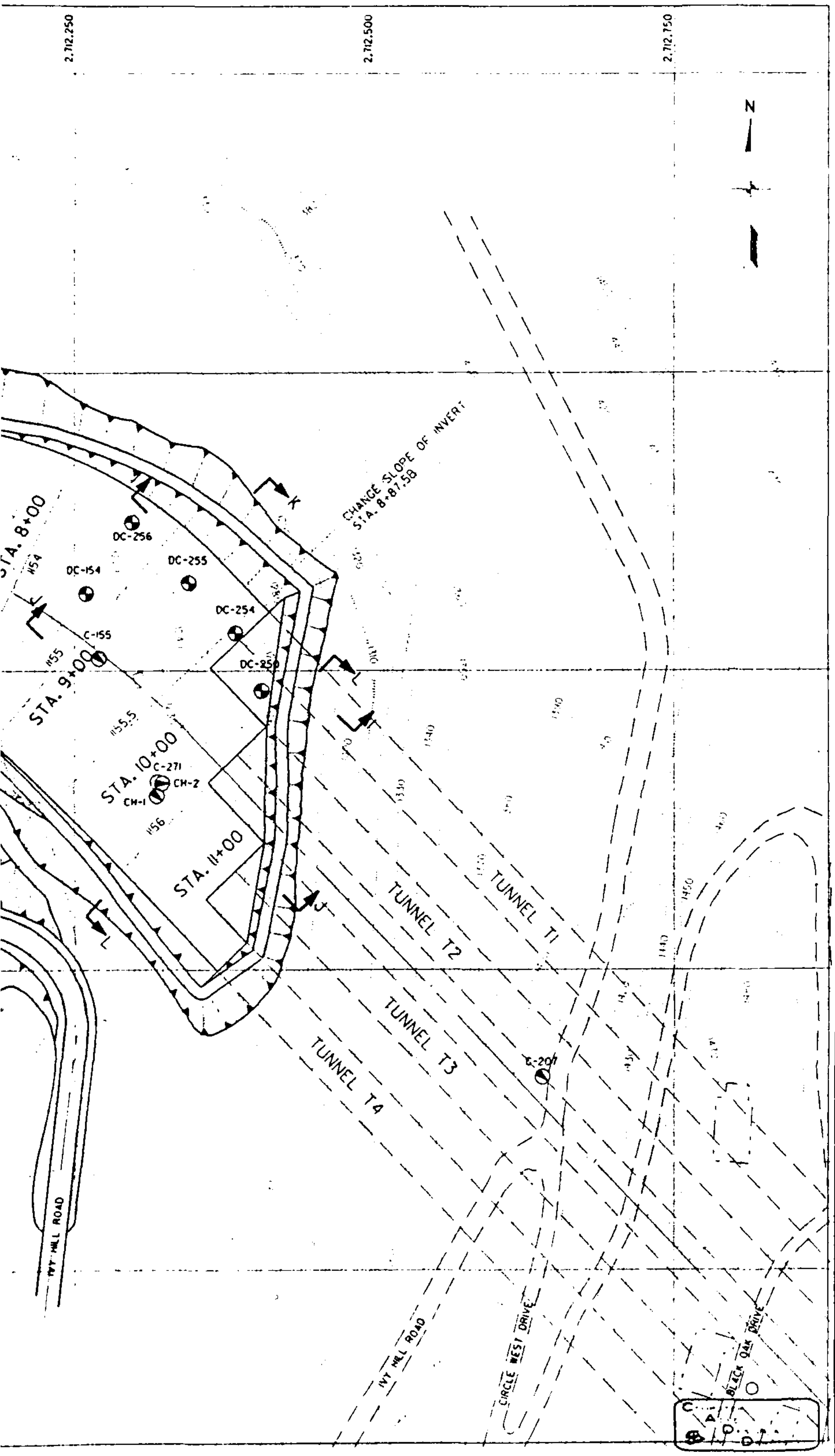
Record Drawing as constructed dated

Computer Aided Design & Drafting Soils Section

PLATE B-1



5
4
D
C
B
A
2,711,500
2,711,750
2,712,000
2,712,250
199,000
198,750
198,500
198,250
198,000
STA. 2+00
BASELINE
FLOW
STA. 6+00
STA. 8+00
STA. 9+00
STA. 10+00
D-251
D-213
D-53A
D-253
DC-256
DC-154
DC-255
C-155
C-271
CH-2
CH-1
M
L & N RAILROAD
RIVER ROAD
KY. HWY. 72
CLOVER FORK
FLOW
PIT HILL ROAD



U.S. ARMY ENGINEER DISTRICT
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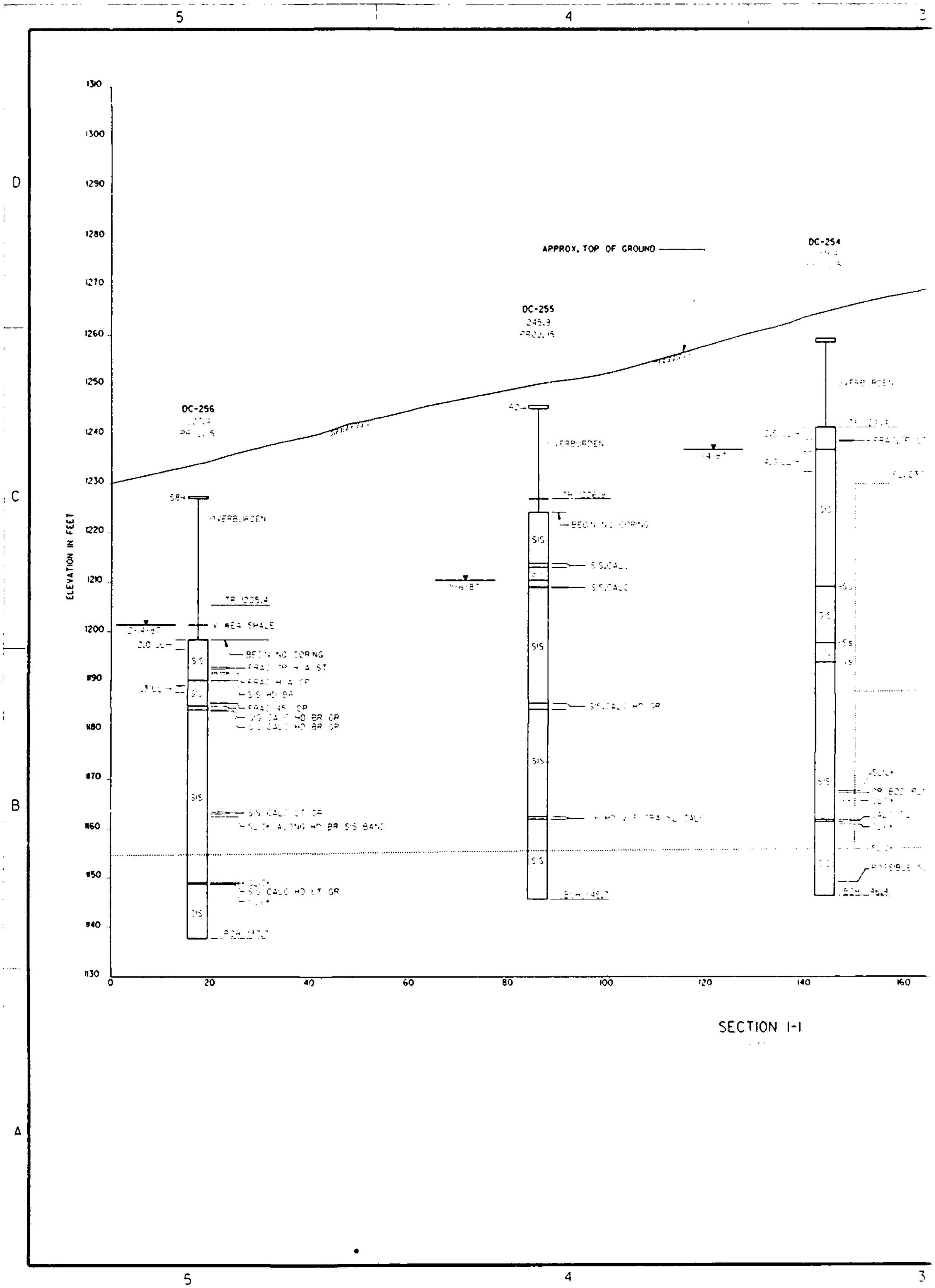
NASHVILLE, TENNESSEE

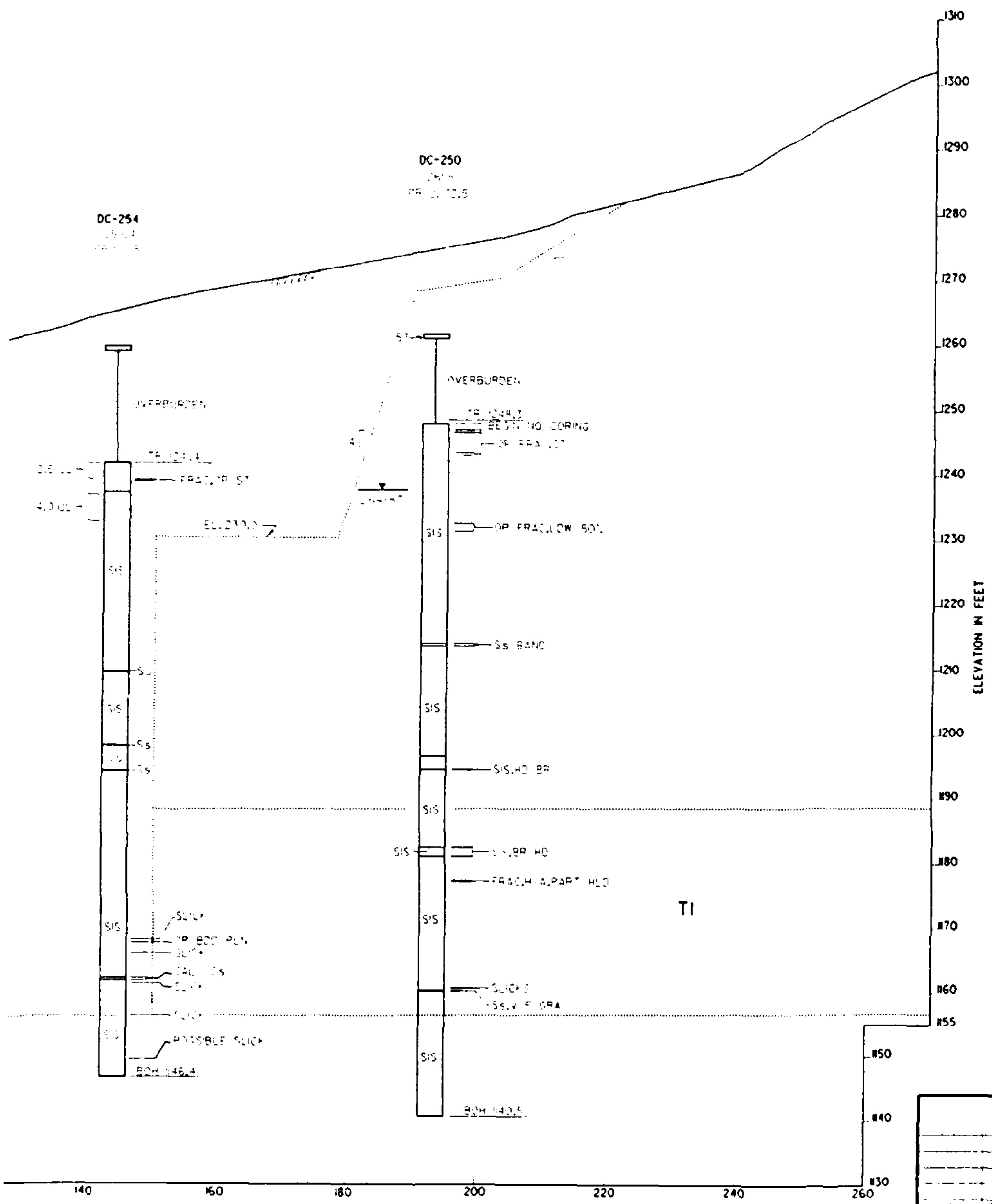
DOWNSTREAM PORTAL
BORING PLAN

01A-64/39.1

PLATE B-2



5
4
3
D
C
B
A
ELEVATION IN FEET
APPROX. TOP OF GROUND
DC-256
DC-255
DC-254
OVERBURDEN
BEGINNING CORING
V. WEA. SHALE
S/S
SECTION I-I



TION I-I

NOTES:
1. FOR LOCATION OF SECTION AND BORING PLAN, SEE DRAWING OIA-64/39.
2. FOR DETAILED LOGS OF BORINGS, SEE DRAWING OIA-64/7 THRU OIA-64/29.
3. FOR GENERAL NOTES, SEE DRAWING OIA-64/7.

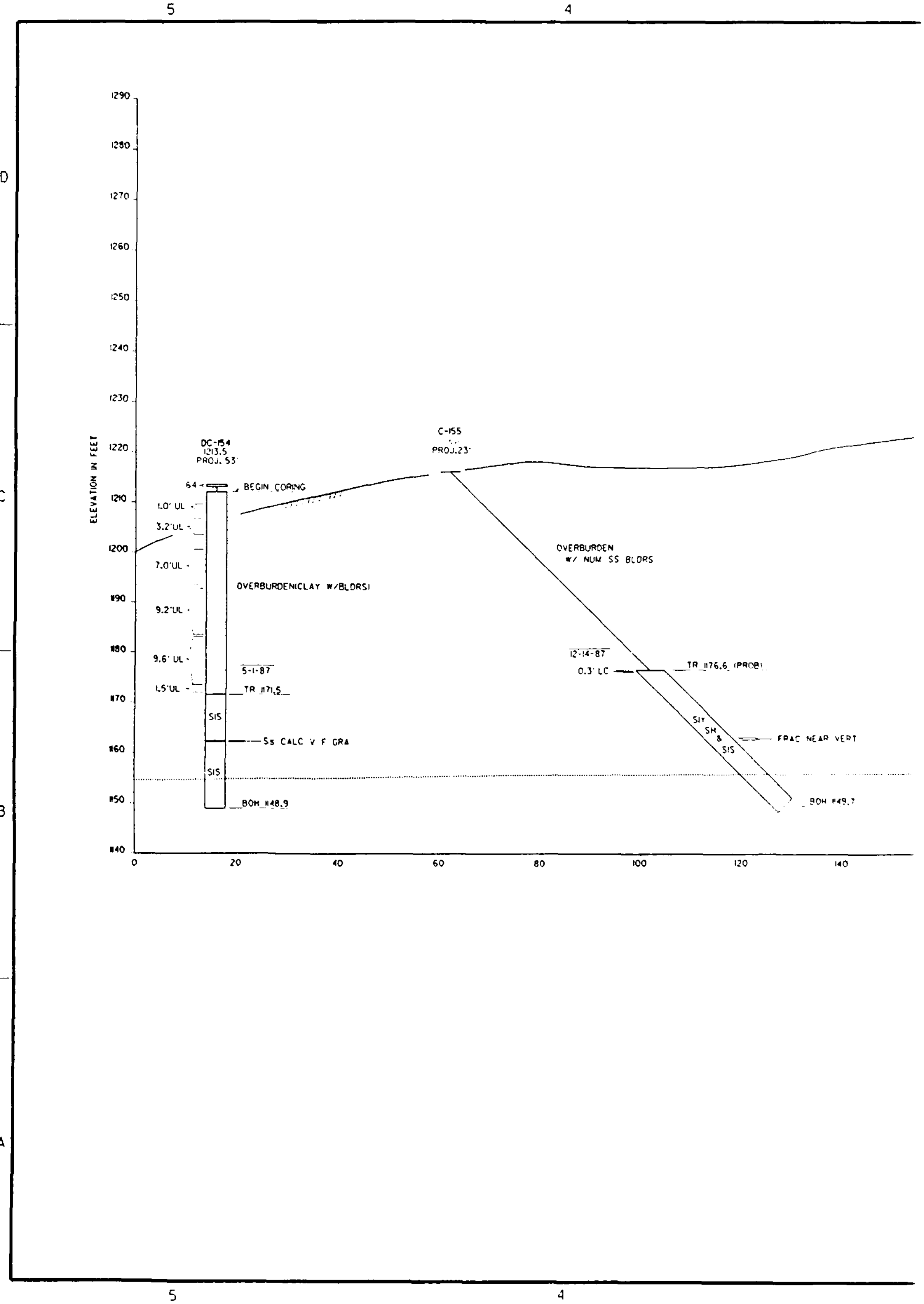
5-31-89 CONFORMING TO REVIEW COMMENTS C.A.G. J.L.S.

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

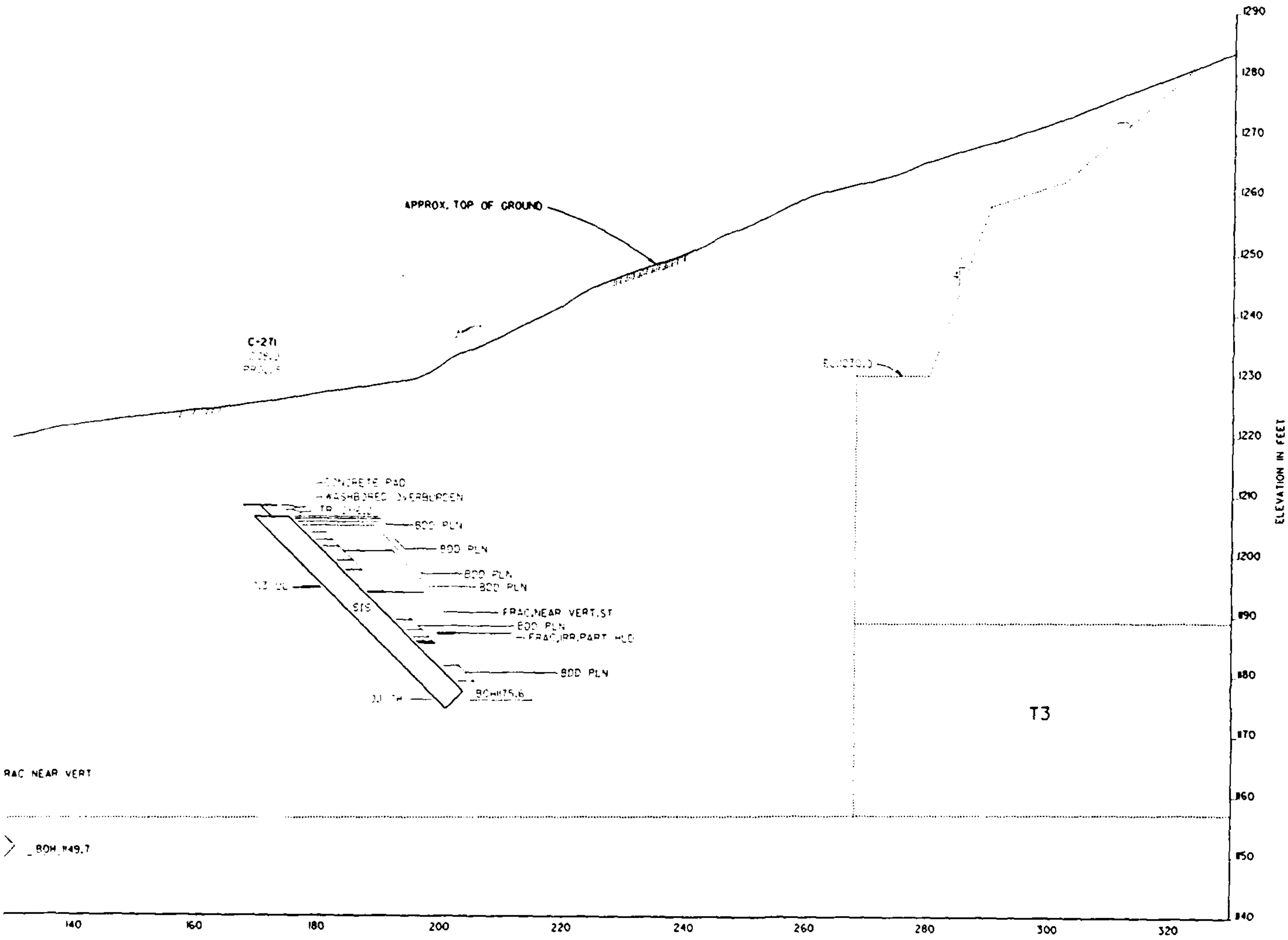
DOWNSTREAM PORTAL
GEOLOGIC SECTION
I-I

OIA-64/40.1

PLATE B-3



ELEVATION IN FEET
DC-154
1213.5
PROJ. 53'
C-155
PROJ. 23'
BEGIN CORING
1.0' UL
3.2' UL
7.0' UL
9.2' UL
9.6' UL
1.5' UL
OVERBURDEN(CLAY W/BLDRS)
5-1-87
TR 1171.5
SIS
Ss CALC V F GRA
BOH 1148.9
OVERBURDEN
W/ NUM SS BLDRS
12-14-87
0.3' LC
TR 1176.6 (PROB)
FRAC NEAR VERT
BOH 1149.7



SECTION J-J

NOTE
1. FOR NOTES, SEE DRAWING OIA-64/40.

U.S. ARMY ENGINEER DISTRICT
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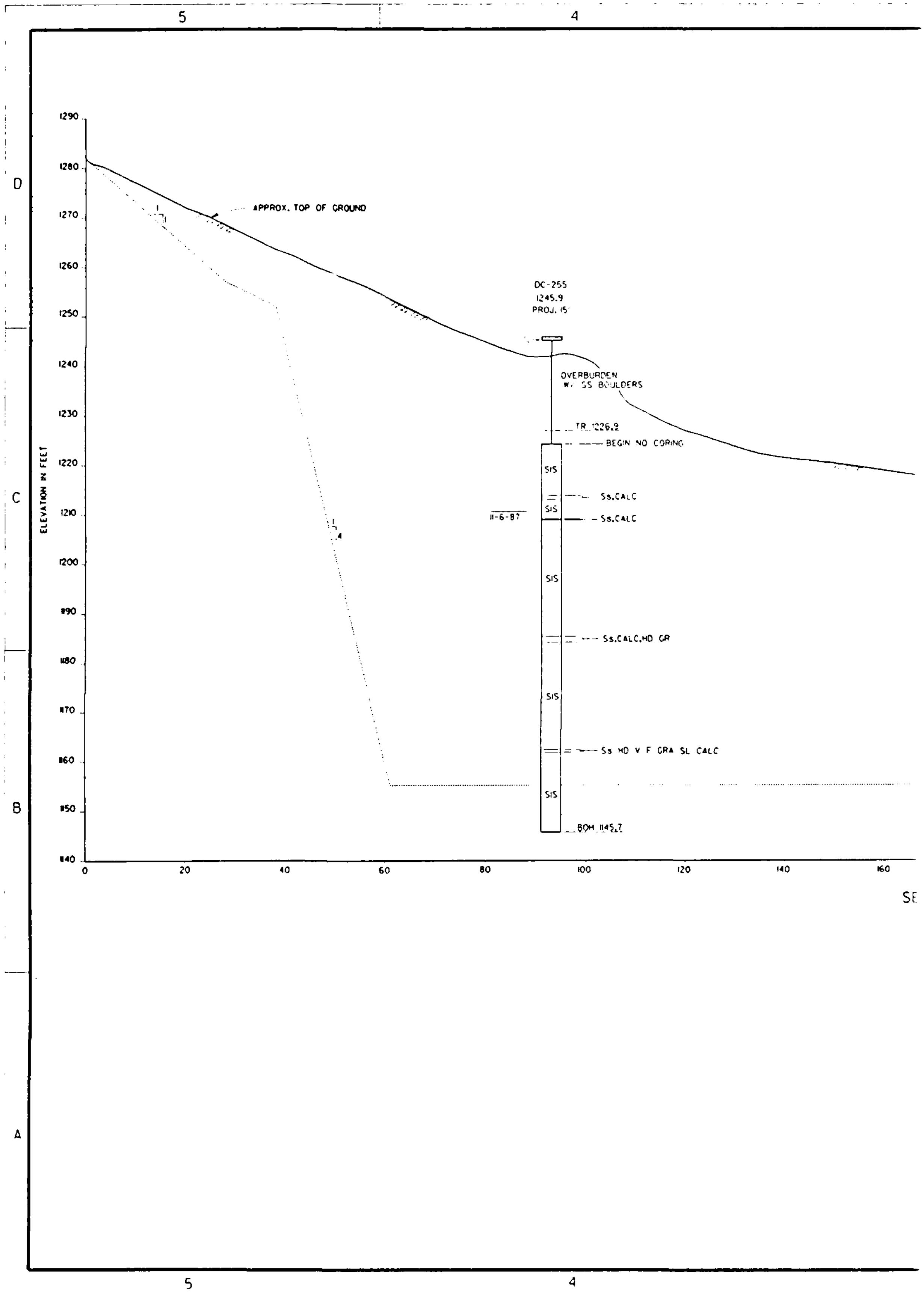
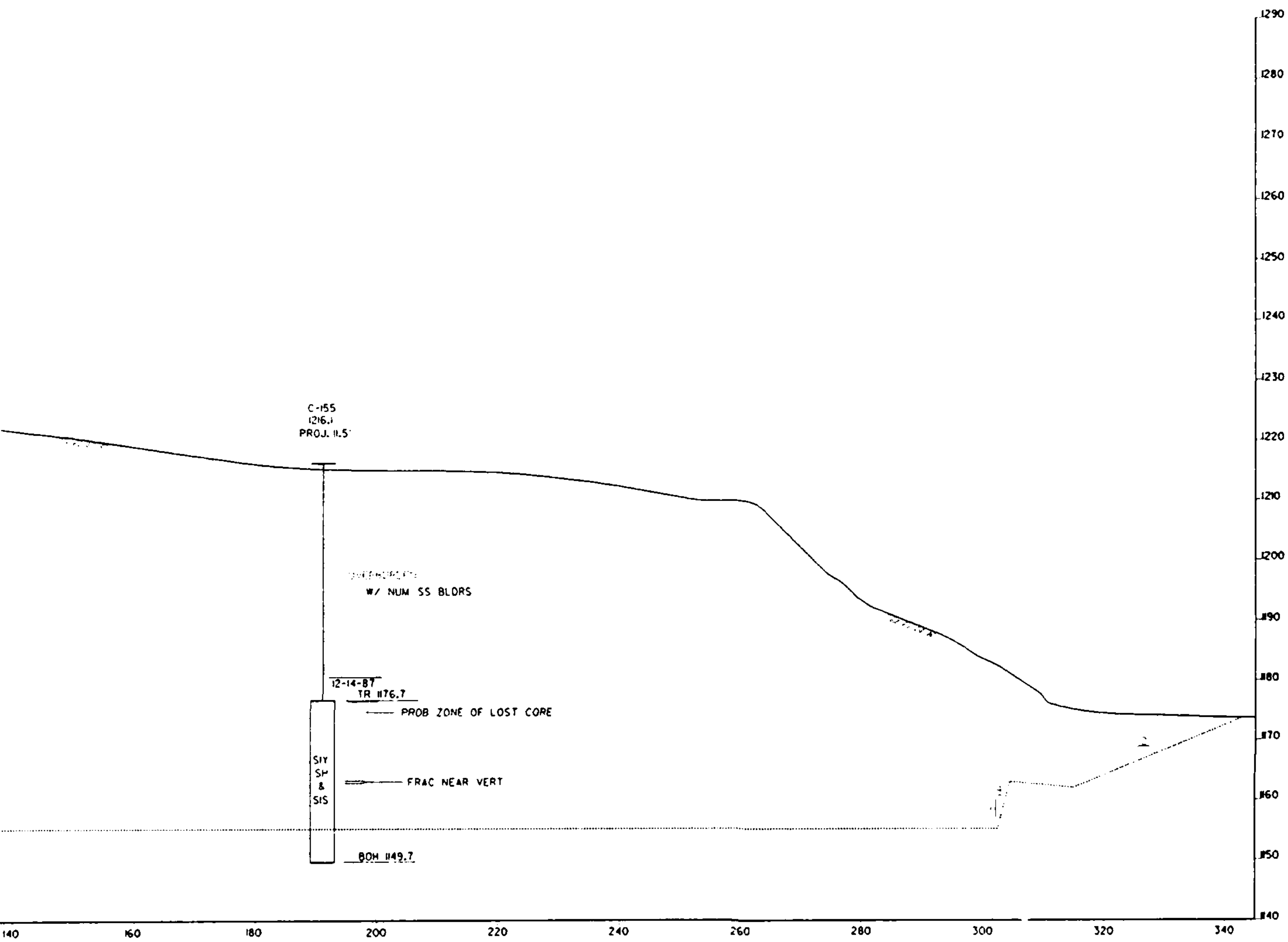
DOWNSTREAM PORTAL
GEOLOGIC SECTION
J-J

OIA-64/41.1

PLATE B-4


5
4
D
C
B
A
APPROX. TOP OF GROUND
DC-255
1245.9
PROJ. 15'
OVERBURDEN
W/ SS BOULDERS
TR. 1226.9
BEGIN NQ CORING
SIS
Ss.CALC
11-6-87
Ss.CALC,HD GR
Ss HD V F GRA SL CALC
BOH 1145.7
ELEVATION IN FEET
1290
1280
1270
1260
1250
1240
1230
1220
1210
1200
1190
1180
1170
1160
1150
1140
0
20
40
60
80
100
120
140
160
SE



SECTION K-K

NOTE
1. FOR NOTES, SEE DRAWING 01A-64/40.

U.S. ARMY ENGINEER DISTRICT
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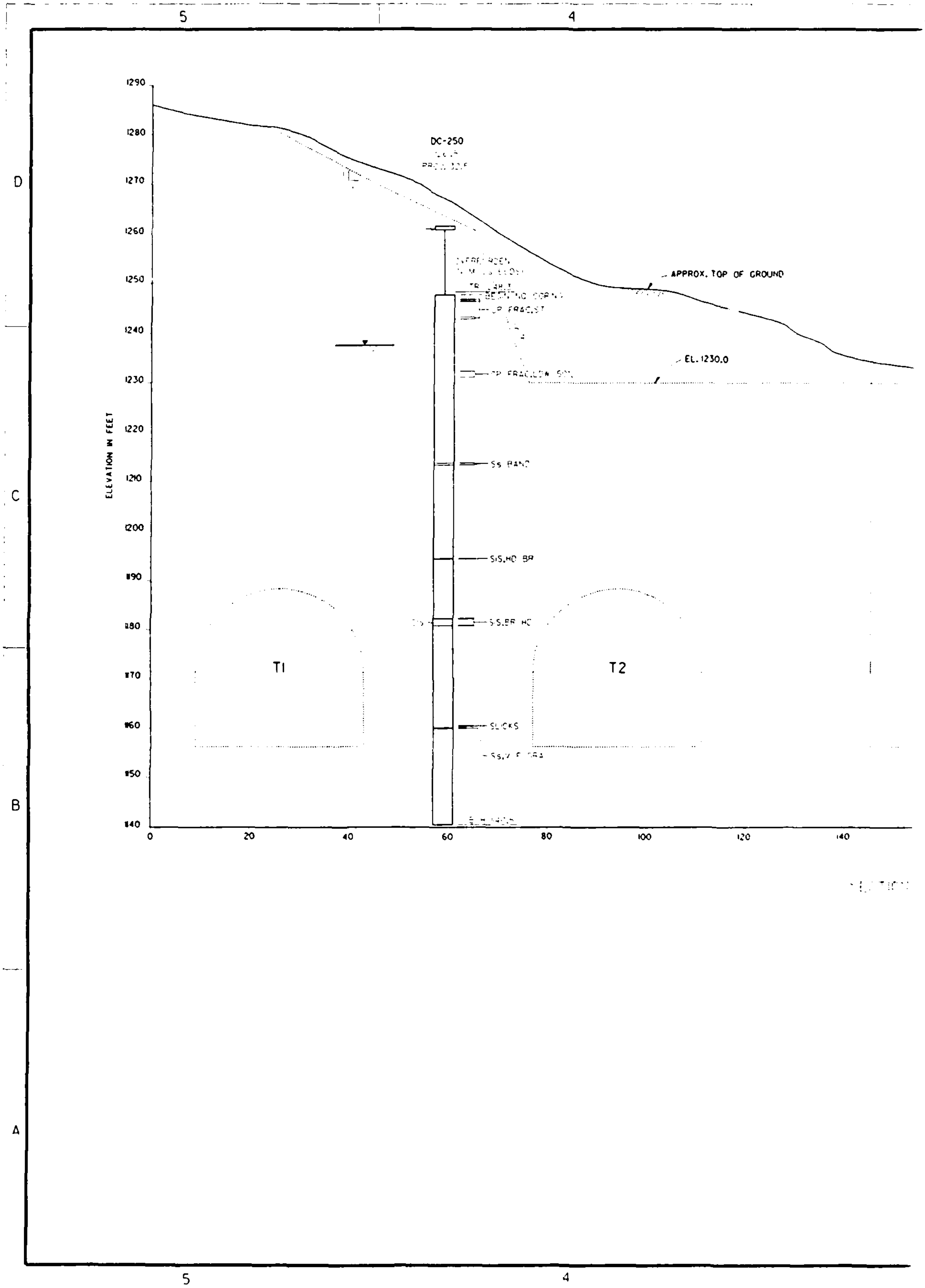
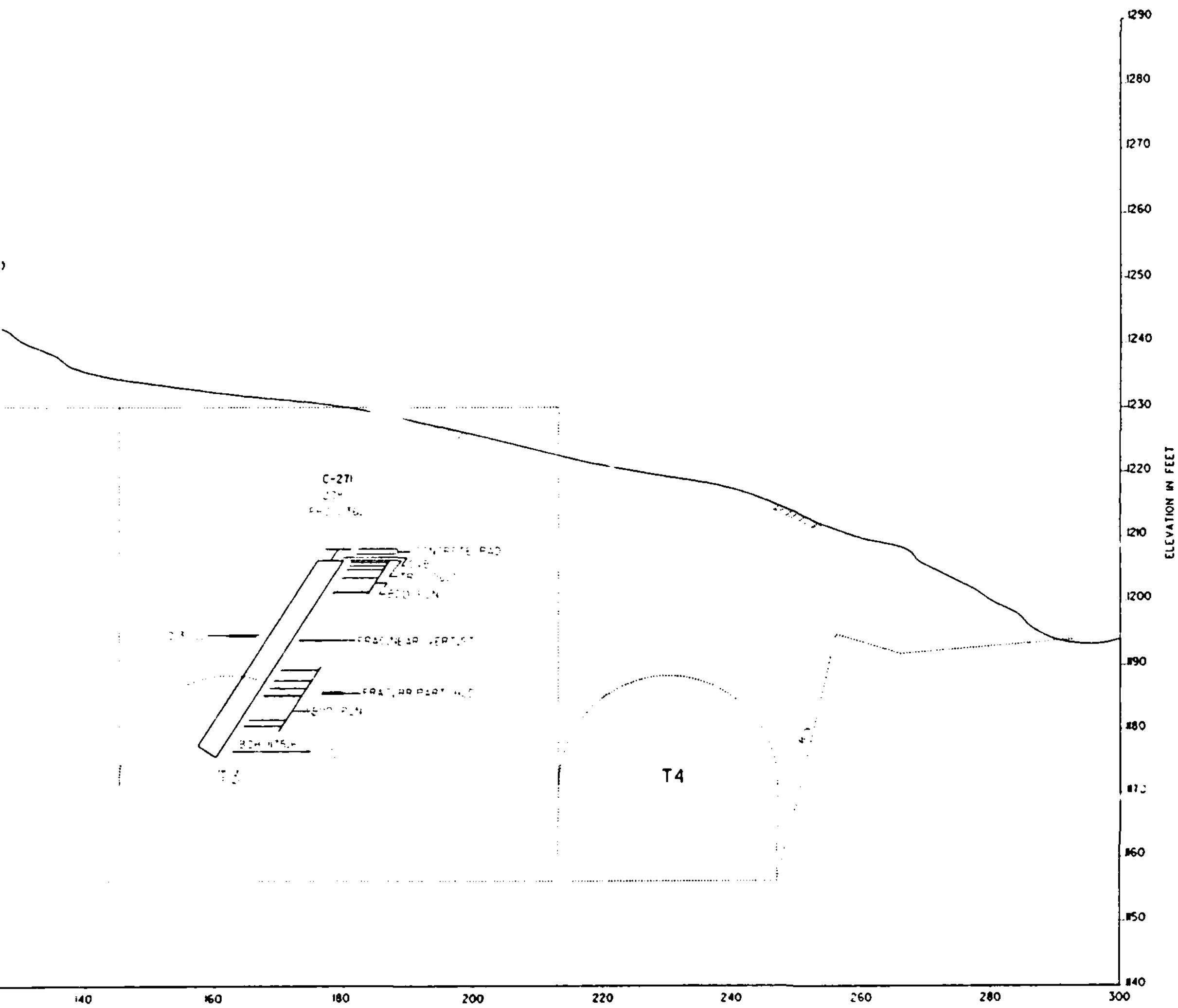
DOWNSTREAM PORTAL
GEOLOGIC SECTION
K-K

01A-64/42.1



5
4
D
C
B
A
DC-250
APPROX. TOP OF GROUND
EL. 1230.0
ELEVATION IN FEET
1290
1280
1270
1260
1250
1240
1230
1220
1210
1200
1190
1180
1170
1160
1150
1140
0
20
40
60
80
100
120
140
SS BAND
SLICKS
T1
T2



NOTE
1. FOR NOTES,SEE DRAWING OIA-64/40.

U.S. ARMY ENGINEER DISTRICT
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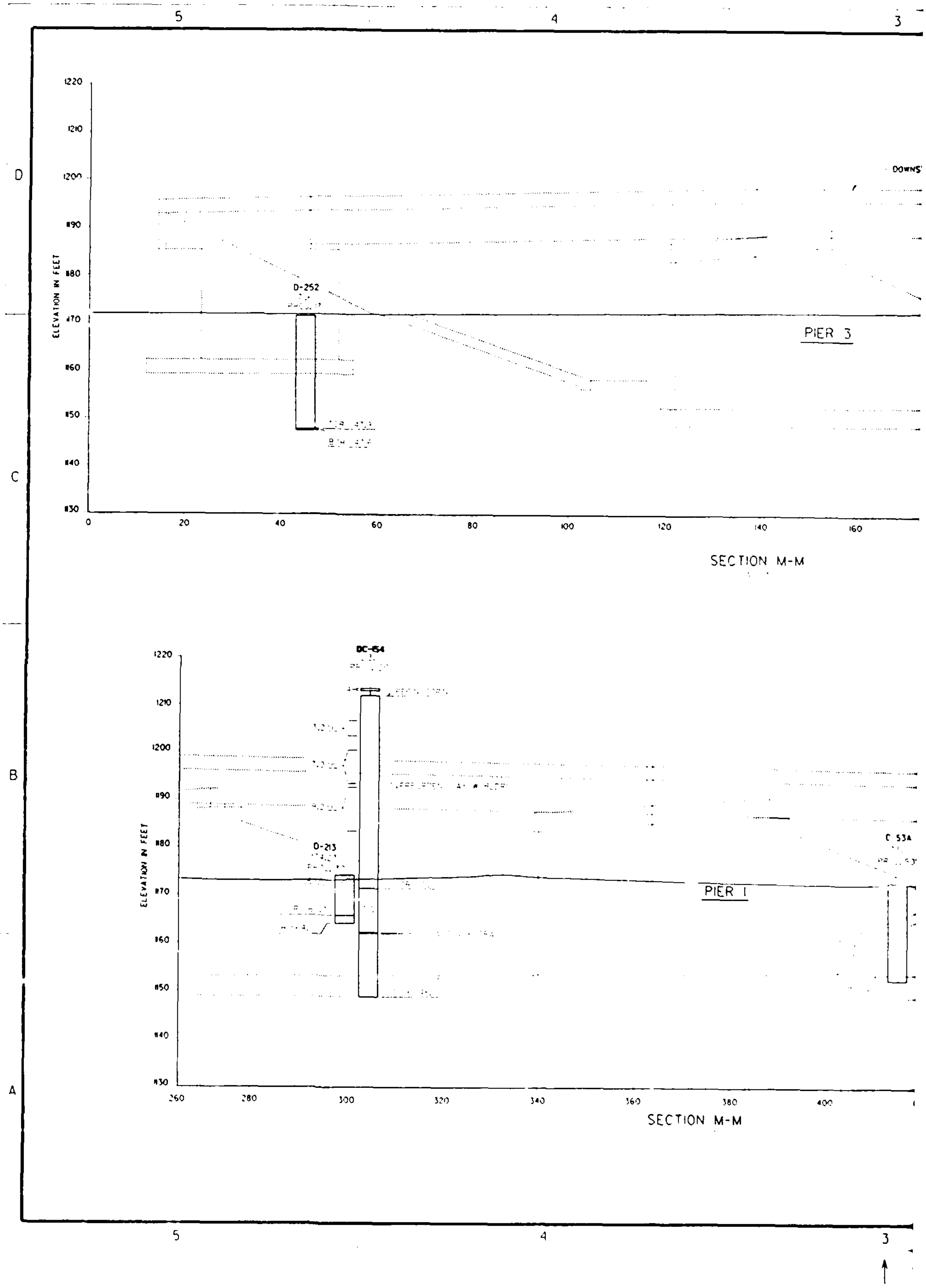
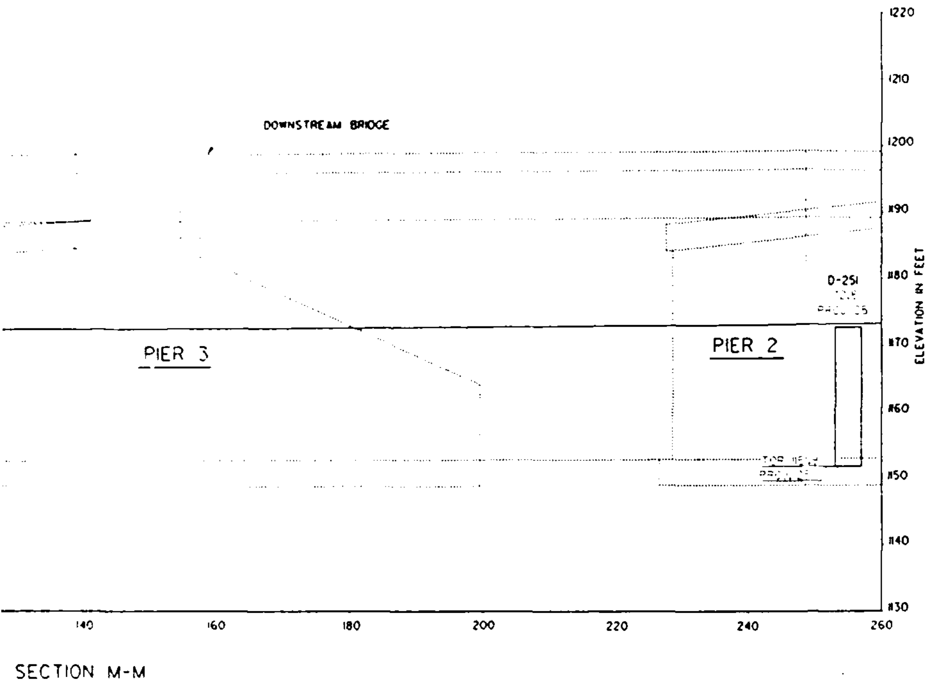
NASHVILLE, TENNESSEE

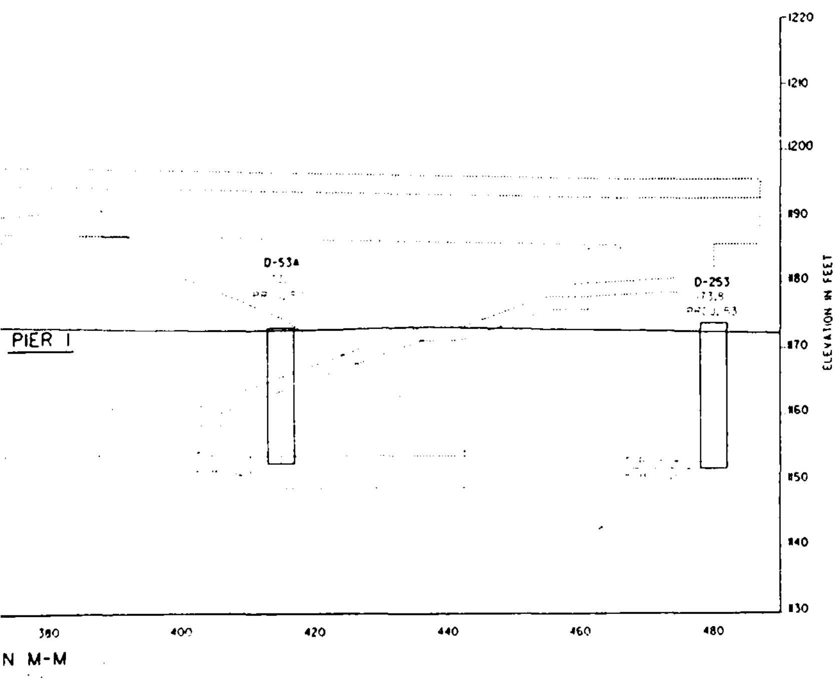
DOWNSTREAM PORTAL
GEOLOGIC SECTION

OIA-64/43.1



5
4
3
D
C
B
A
1220
1210
1200
1190
1180
1170
1160
1150
1140
1130
ELEVATION IN FEET
D-252
PIER 3
DOWNS
0
20
40
60
80
100
120
140
160
SECTION M-M
DC-154
D-213
C 53A
PIER 1
260
280
300
320
340
360
380
400
SECTION M-M
5
4
3





NOTE:
1. FOR NOTES, SEE DRAWING OIA-64/40.

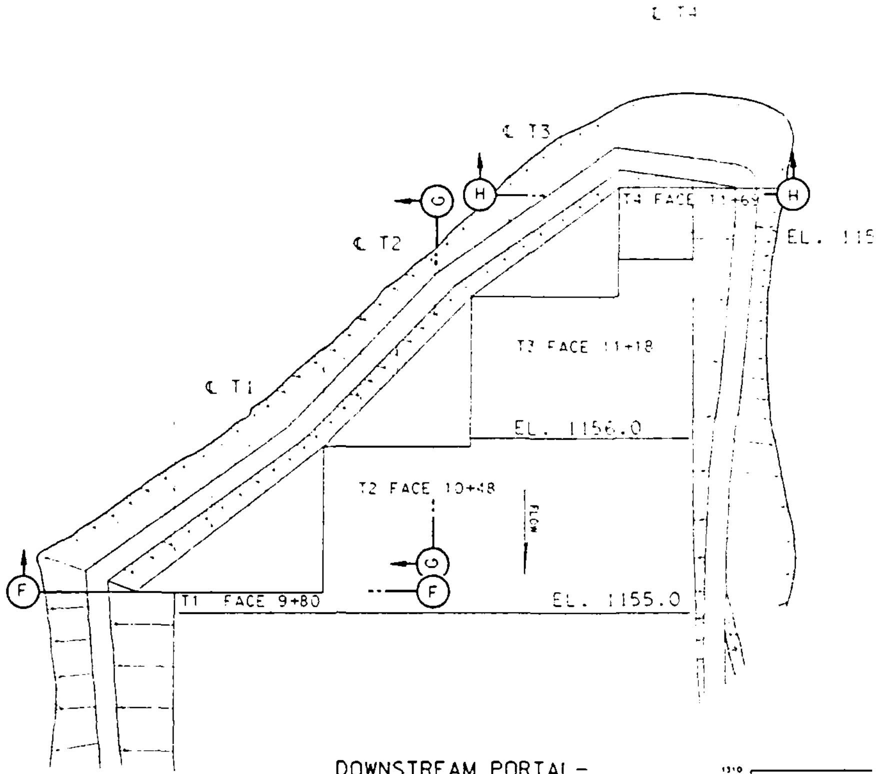
5-31-89 CONFORMING TO REVIEW COMMENTS

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

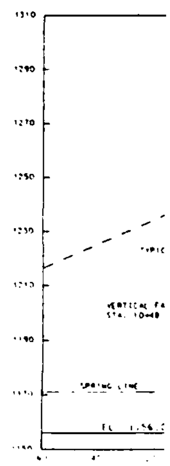
DOWNSTREAM PORTAL
GEOLOGIC SECTION
M-M

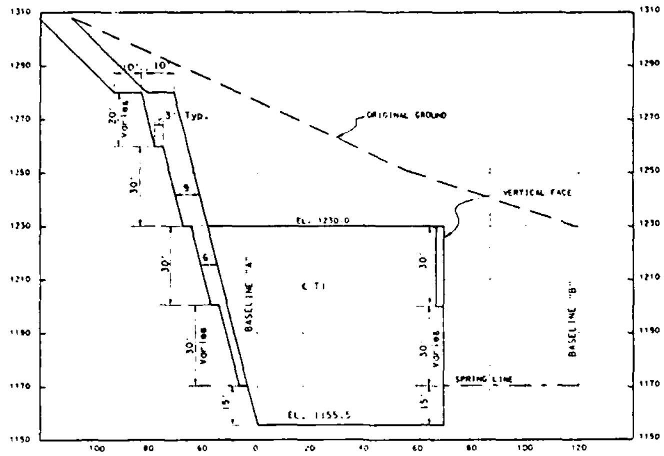
OIA-64/44.1

PLATE B-7

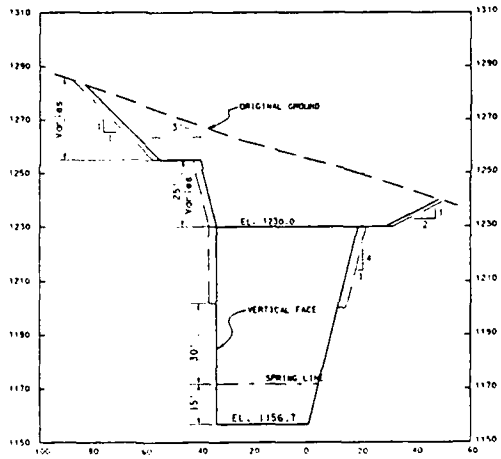


DOWNSTREAM PORTAL-
CROSS SECTION LOCATION PLAN

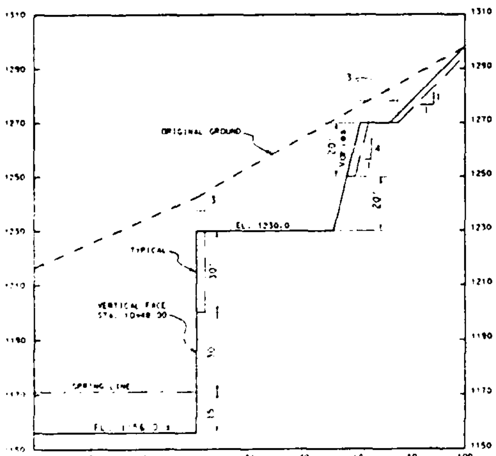




DOWNSTREAM PORTAL
SECTION F



DOWNSTREAM PORTAL
SECTION H



DOWNSTREAM PORTAL
SECTION G

Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

Drawn By: CAG
Checked By: PR

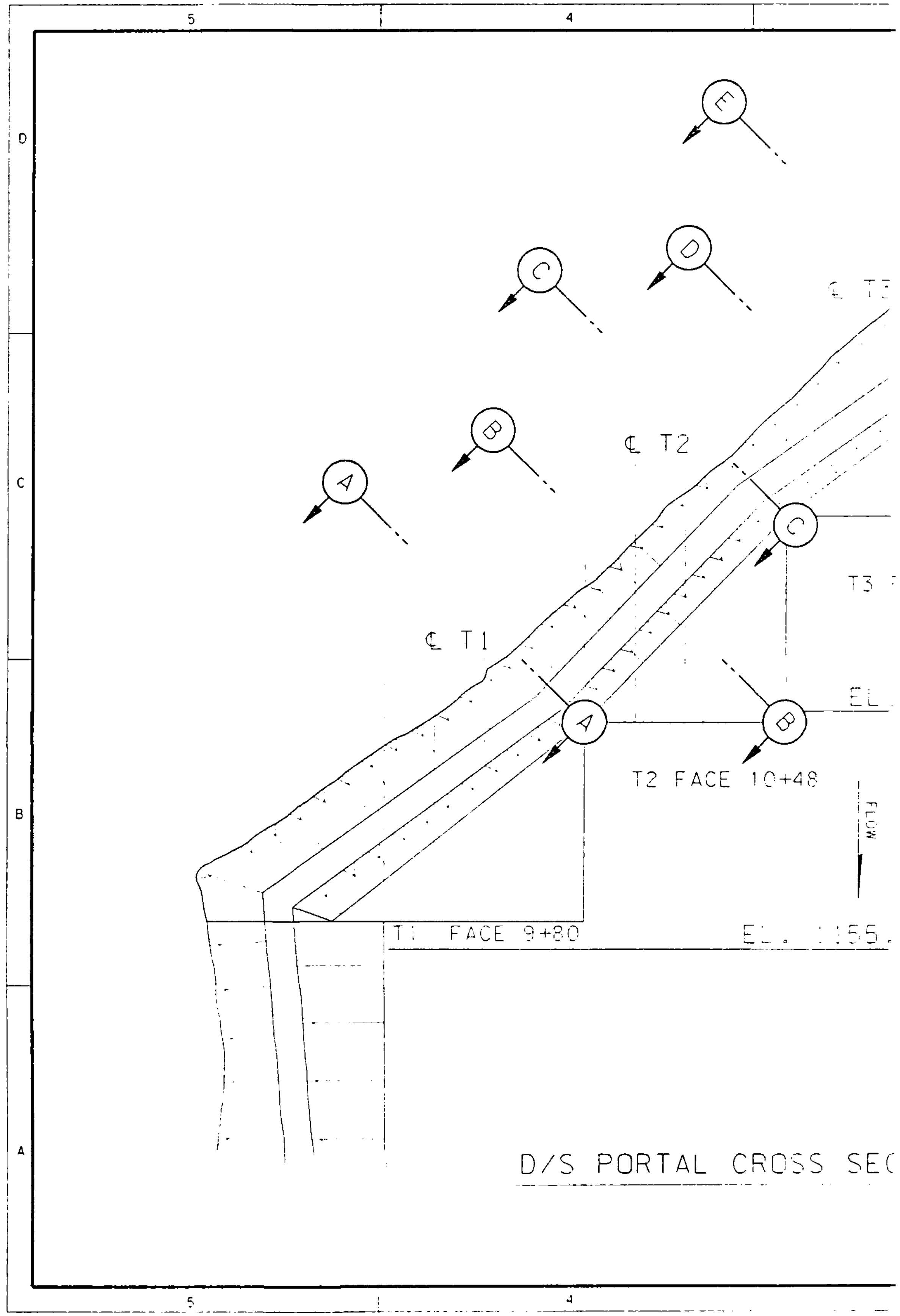
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION TUNNELS
DOWNSTREAM PORTAL
EXCAVATION PLAN, CROSS SECTIONS AND CROSS SECTION LOCATIONS

Approved By:

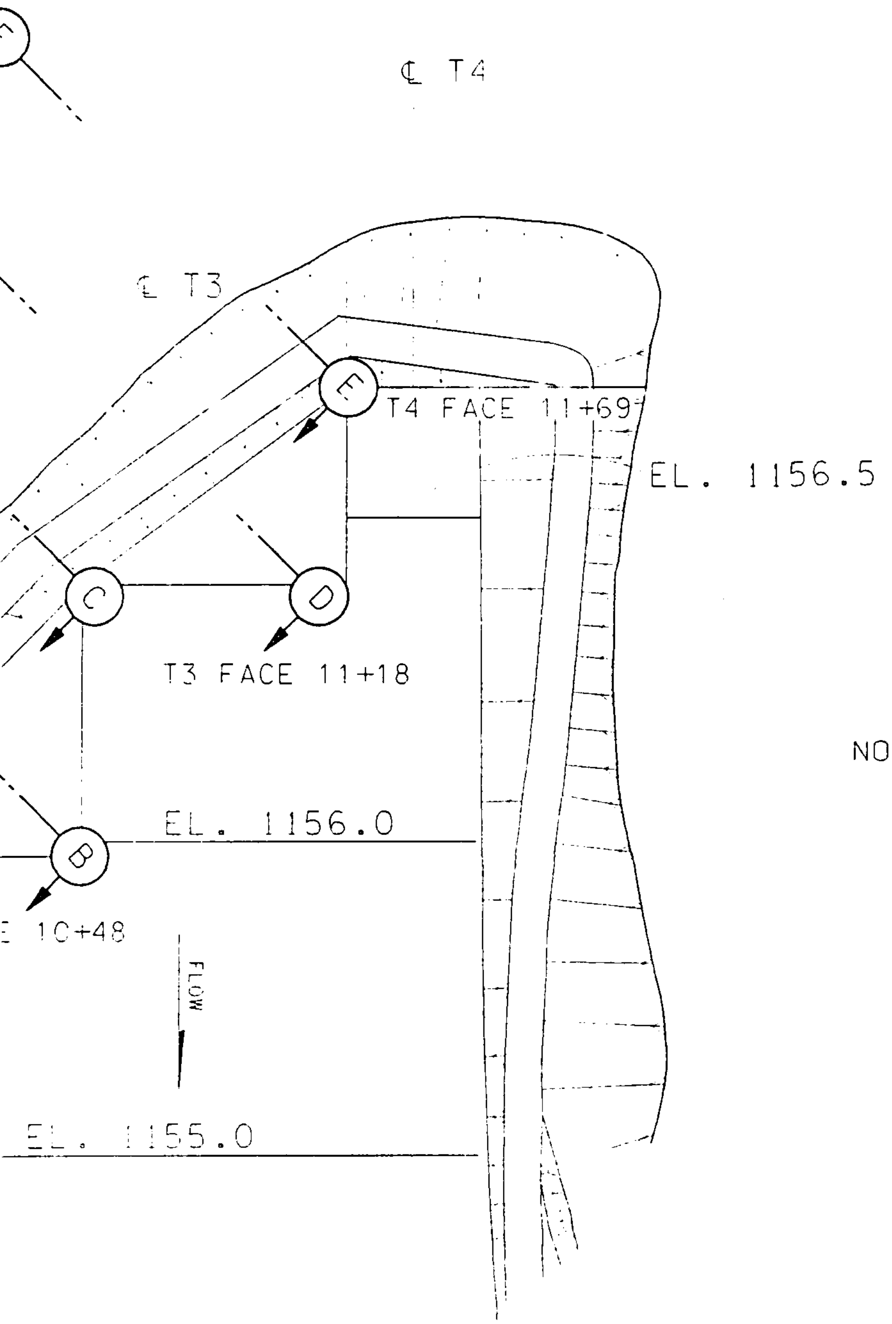
Drawing Number: Q1A-4383

Computer Aided Design & Drafting — Soils Section

PLATE B-8



5
4
D
C
B
A
E
D
C
B
A
℄ T3
℄ T2
℄ T1
C
T3
EL.
A
B
T2 FACE 10+48
FLOW
T1 FACE 9+80
EL. 1155.
D/S PORTAL CROSS SEC



NOTE:
THESE CROSS-SECTIONS SHOWN ON PLATE B-10.

40' 0 40'

Graphic Scale

CROSS SECTION LOCATION PLAN

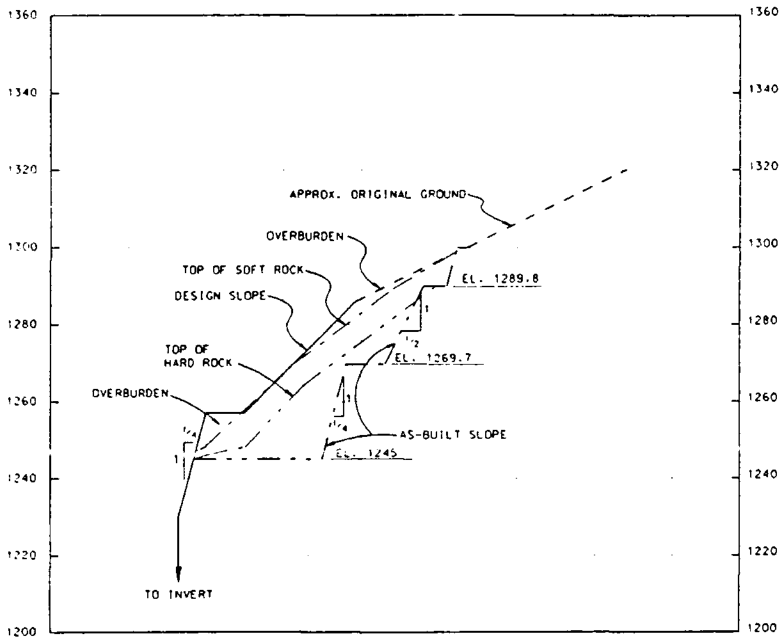
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION TUNNELS

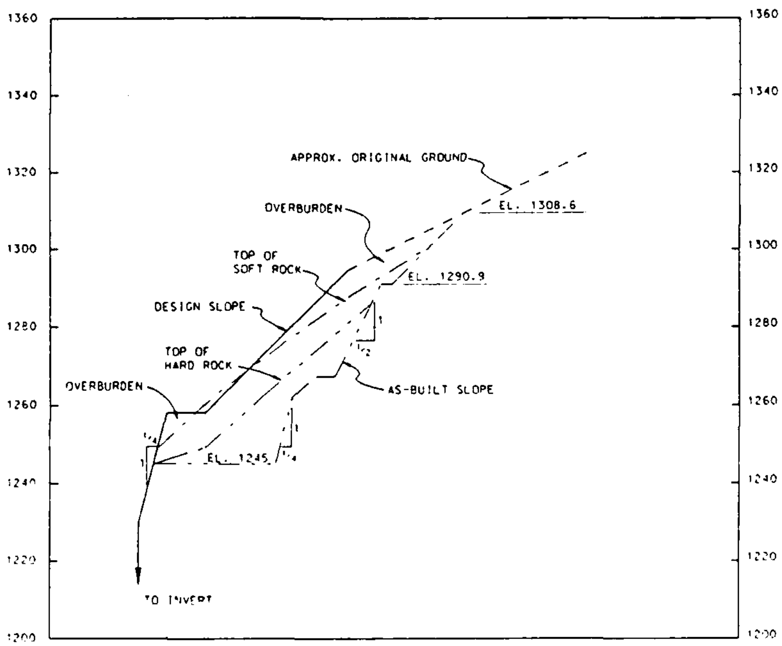
CROSS SECTION LOCATION PLAN
DOWNSTREAM PORTAL

Drawn By: C.A.
Checked By: P.E.
Date: FEB 1994
Record Drawing as constructed dated
Drawing Number: Q1A-4384

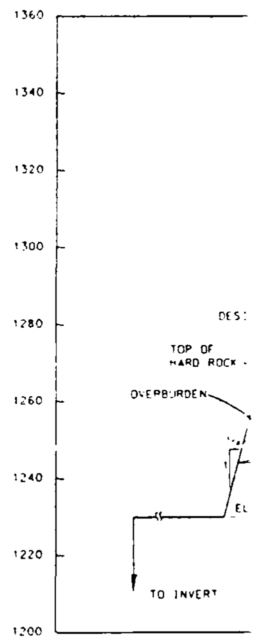
PLATE B-9

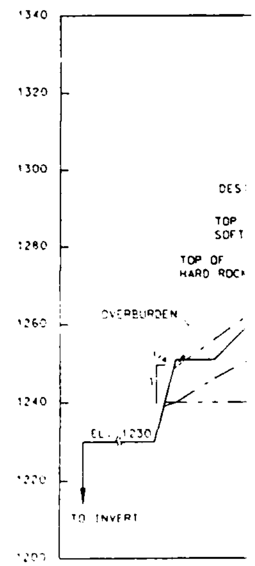


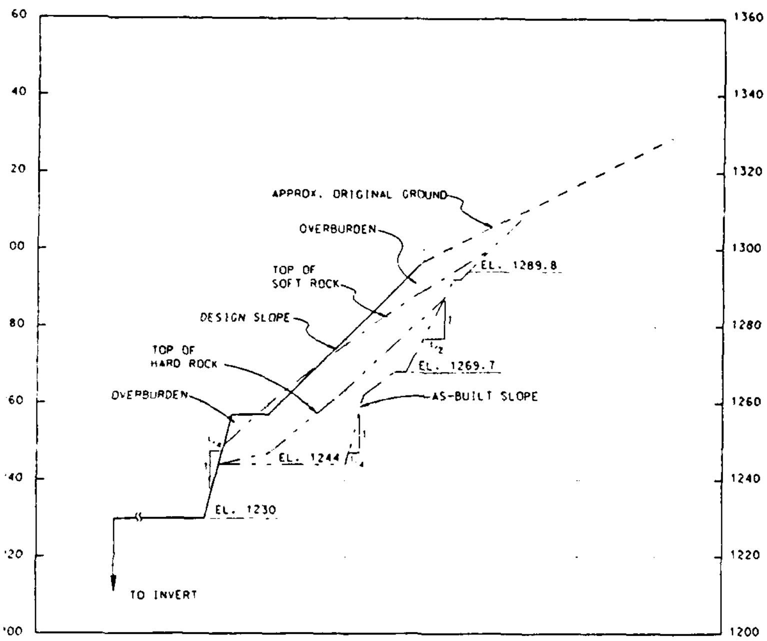
DOWNSTREAM PORTAL
SECTION A



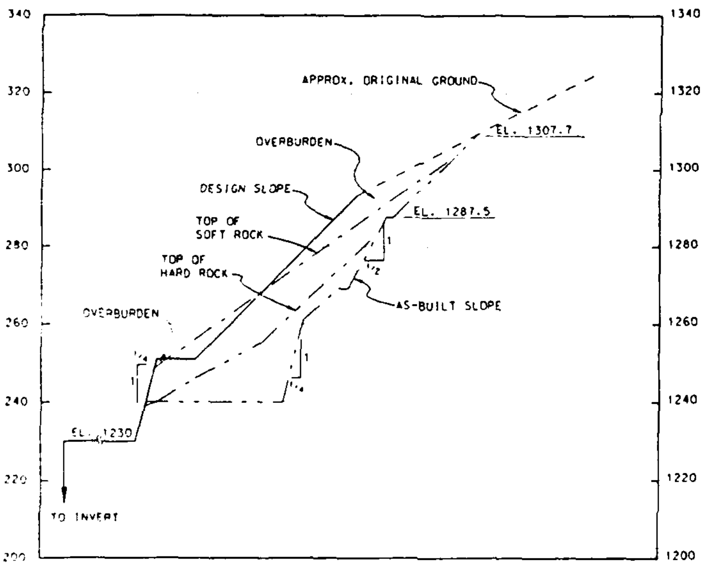
DOWNSTREAM PORTAL
SECTION C



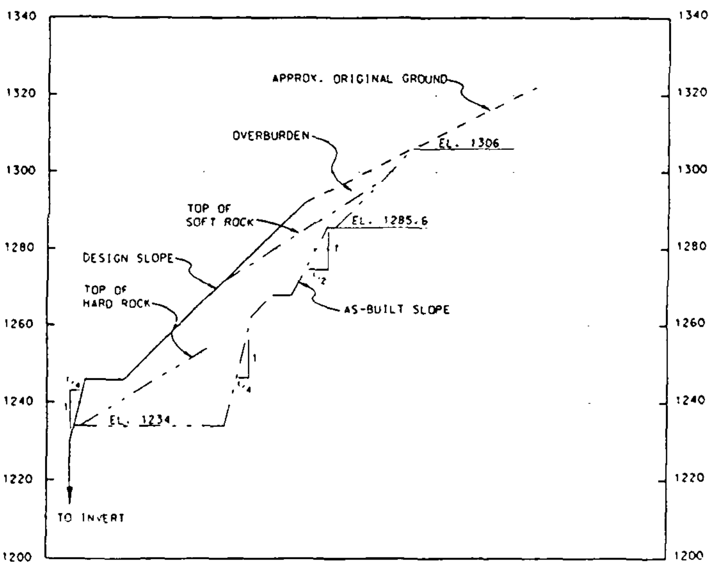




DOWNSTREAM PORTAL
SECTION B



DOWNSTREAM PORTAL
SECTION D



DOWNSTREAM PORTAL
SECTION E

20' 0 20'
Graphic Scale

NOTE:
SEE CROSS-SECTION LOCATION PLAN, PLATE B-9.

REV.	DESCRIPTION	DATE	BY	APPROVED

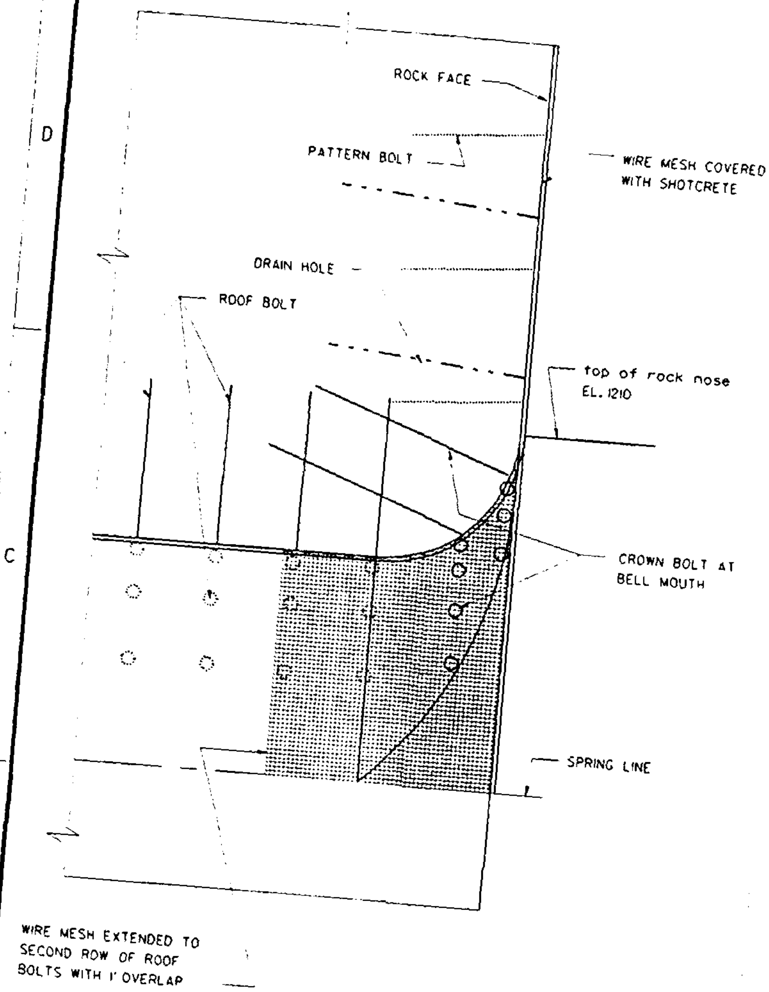
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION TUNNELS
DOWNSTREAM PORTALS
DESIGN & AS-BUILT CROSS-SECTIONS
PERPENDICULAR TO BACKSLOPE

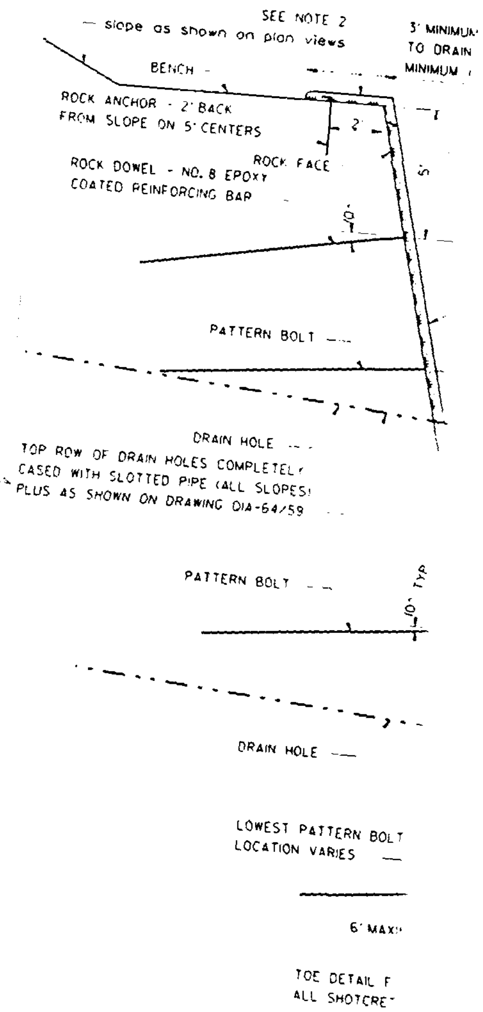
Drawn By: CAG
Checked By: PR
PR GEOLOGIST
Approved By:
CHIEF, GEOTECHNICAL BRANCH
CHIEF, ENGINEERING DIVISION
Date: FEB 1994
Scale: 1"=20'
Record Drawing as constructed
Drawing Number: Q1A-4/385

Computer Soils Aided Section Design & Drafting

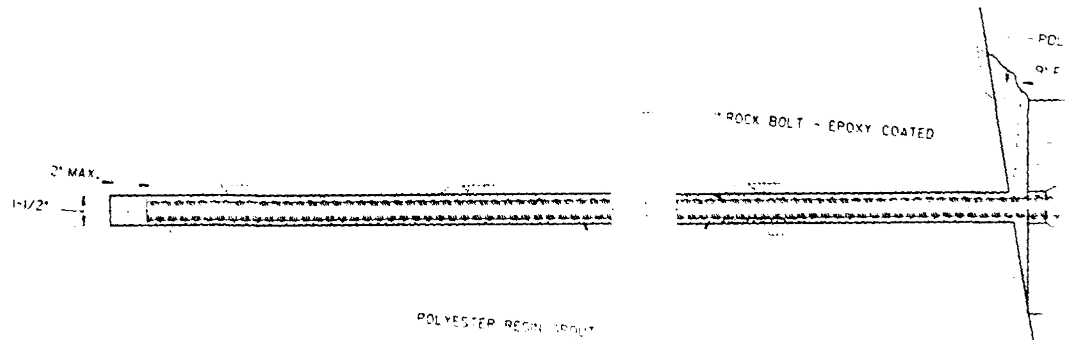
PLATE B-10



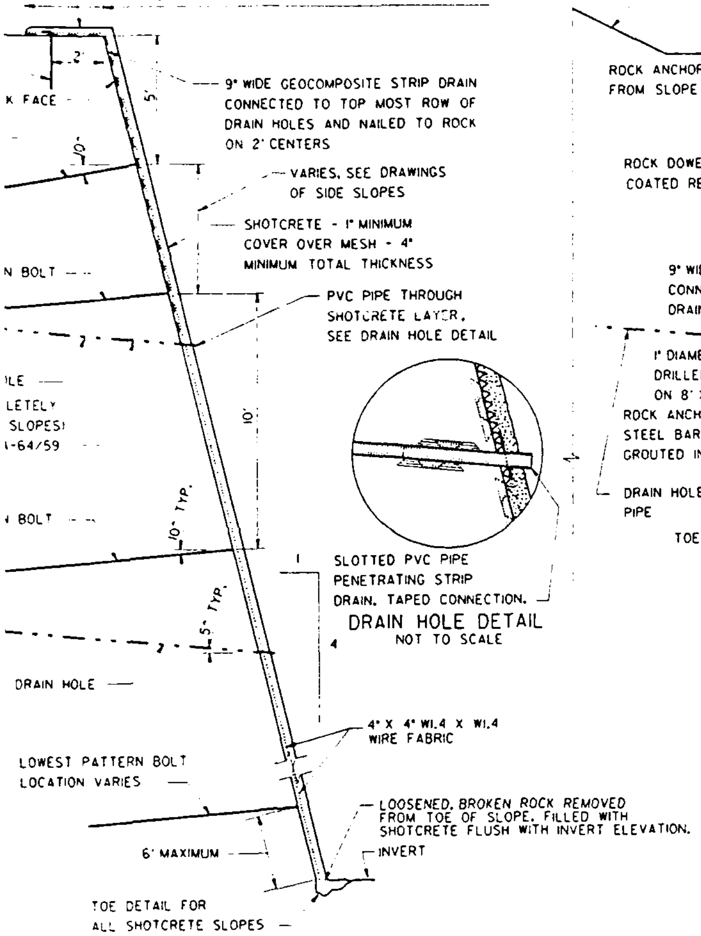
DETAIL
WIRE MESH INSTALLATION
AT BELL MOUTH
(UPSTREAM PORTAL ONLY)
SCALE: 1" = 5'



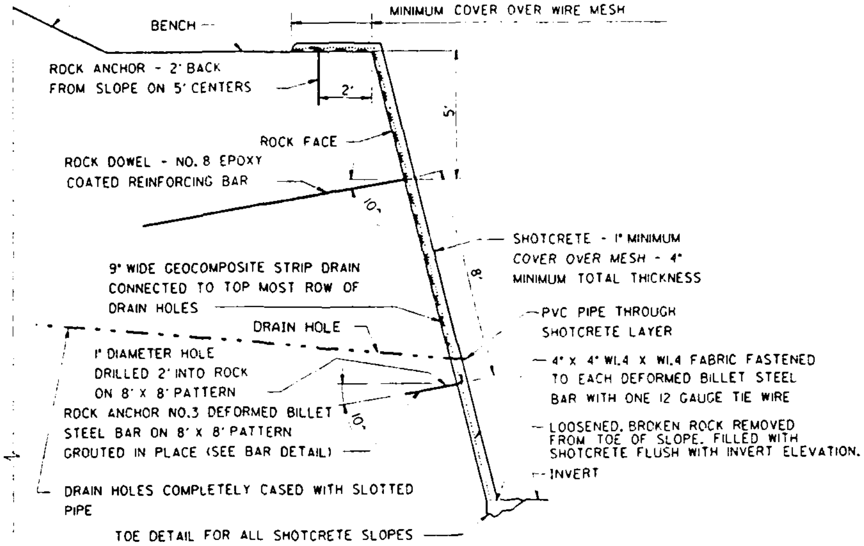
DETAIL
SLOPE TREATMENT FOR 4 ON 1
AND ROCKNOSE SIDE SLOPES TO RECEIVE S
SCALE: 1" =



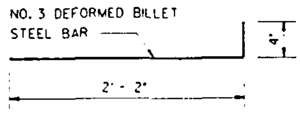
DETAIL
ROCK BOLT
NOT TO SCALE



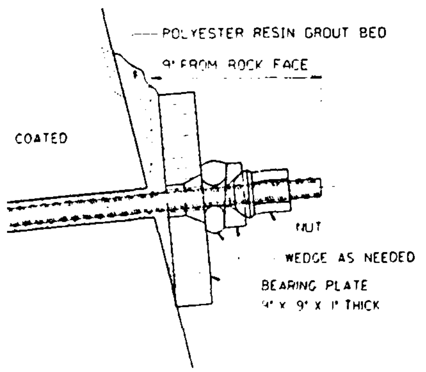
DETAIL
MENT FOR 4 ON 1 SLOPES OVER 40' HIGH
ES TO RECEIVE SHOTCRETE (STEEPER THAN 4V ON 1H)
SCALE: 1" = 2.5'



DETAIL
SLOPE TREATMENT FOR SLOPES UNDER 40'
HIGH - SHOTCRETE, DOWELS AND DRAINAGE ONLY
SCALE: 1" = 2.5'



ROCK ANCHOR BAR DETAIL
NOT TO SCALE



NOTE:
CONICAL NUT AND WEDGE ASSEMBLY SHOWN. OTHER SYSTEM AS APPROVED MAY BE USED

NOTES:

1. SPACING ON ROCK DOWELS AND ROCK BOLTS TYPICAL EXCEPT AS MODIFIED IN OTHER DRAWINGS.
2. SHOTCRETE WAS EXTENDED UP-SLOPE TO COVER ALL SILTSTONE SURFACES.

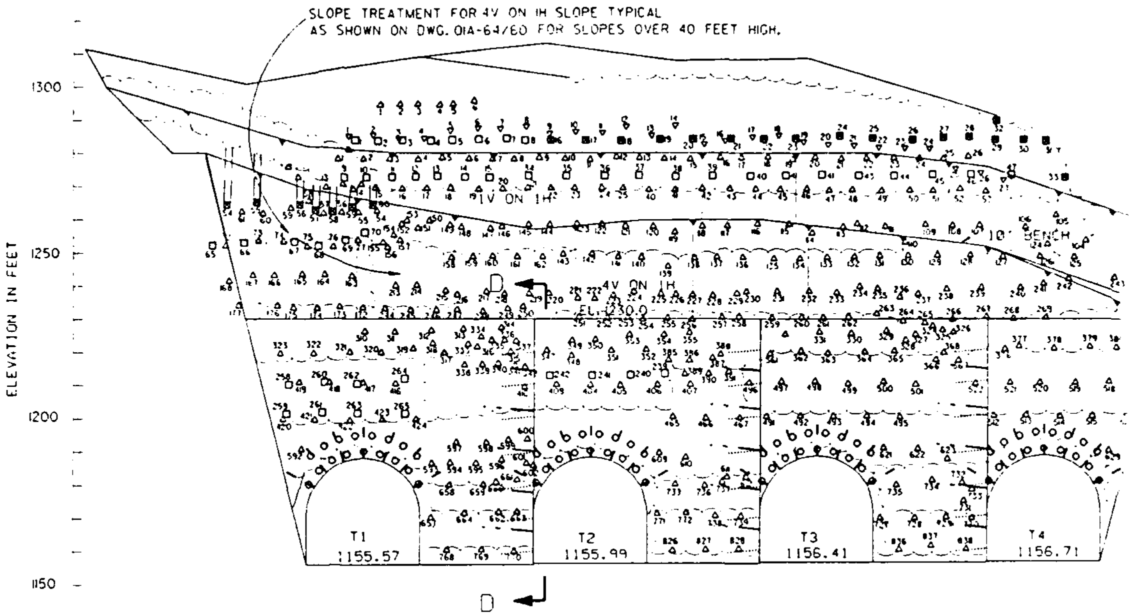
3	2-2-94	AS CONSTRUCTED	MAR	
2	6-30-89	ADDED DRAIN HOLE DETAIL	E.P.D.	J.L.S.
1	5-31-89	CONFORMING TO REVIEW COMMENTS	E.P.D.	J.L.S.

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

PORTAL
ROCK SLOPE TREATMENT DETAILS

OIA-64/60.3

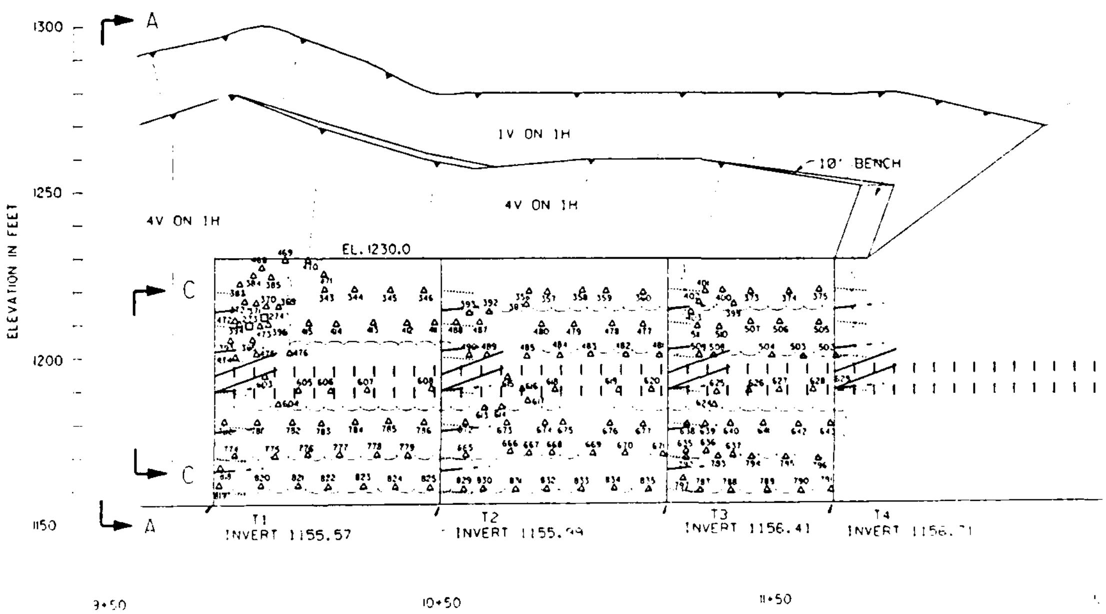
PLATE B-11



SECTION A-A

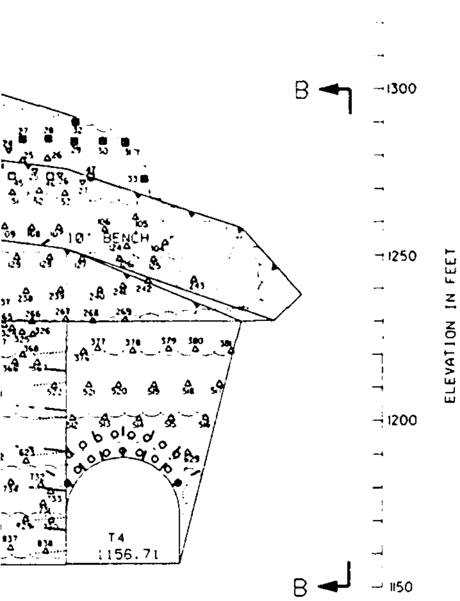
SCALE: 1"= 20'

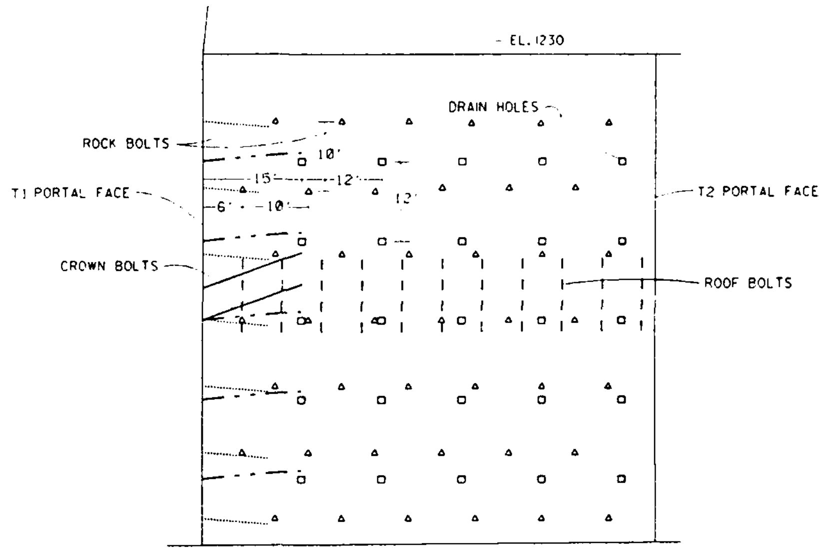
INVERT ELEVATION SHOWN AT TOP OF 8" CONCRETE BASE SLAB.



SECTION B-B

SCALE: 1"= 20'

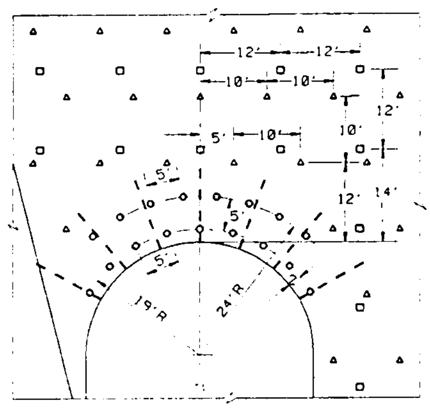




SECTION D-D

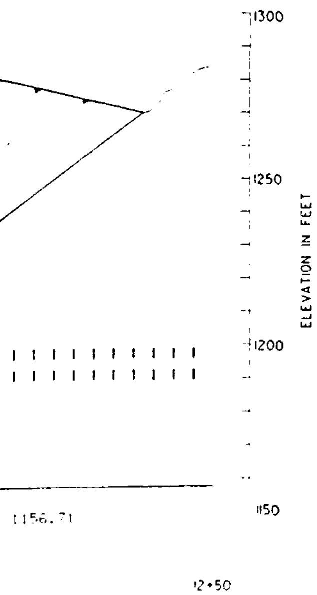
SCALE: 1"= 10'

SPACING SHOWN TYPICAL.



SECTION C-C

SCALE: 1"= 10'



NOTES:

1. GENERAL NOTES ON DRAWING 01A-64/2.
2. SLOPE TREATMENT DETAILS AS SHOWN ON DRAWING 01A-64/60.
3. GENERAL PLAN OF D/S PORTAL SHOWN ON DRAWING 01A-64/61.
4. SUPPORT DETAILS FOR TUNNELS SHOWN ON DRAWING 01A-64/72.
5. LOCATION, NUMBER, & LENGTH OF ROCK BOLTS, DOWELS & DRAINS MAY BE VARIED AT THE DIRECTION OF CONTRACTING OFFICER TO SUIT ROCK CONDITIONS EXPOSED AS EXCAVATION PROGRESSES.
6. ALL VERTICAL AND 1H ON 4V ROCK FACES TO BE COVERED WITH WIRE MESH OR FIBER REINFORCED SHOTCRETE.

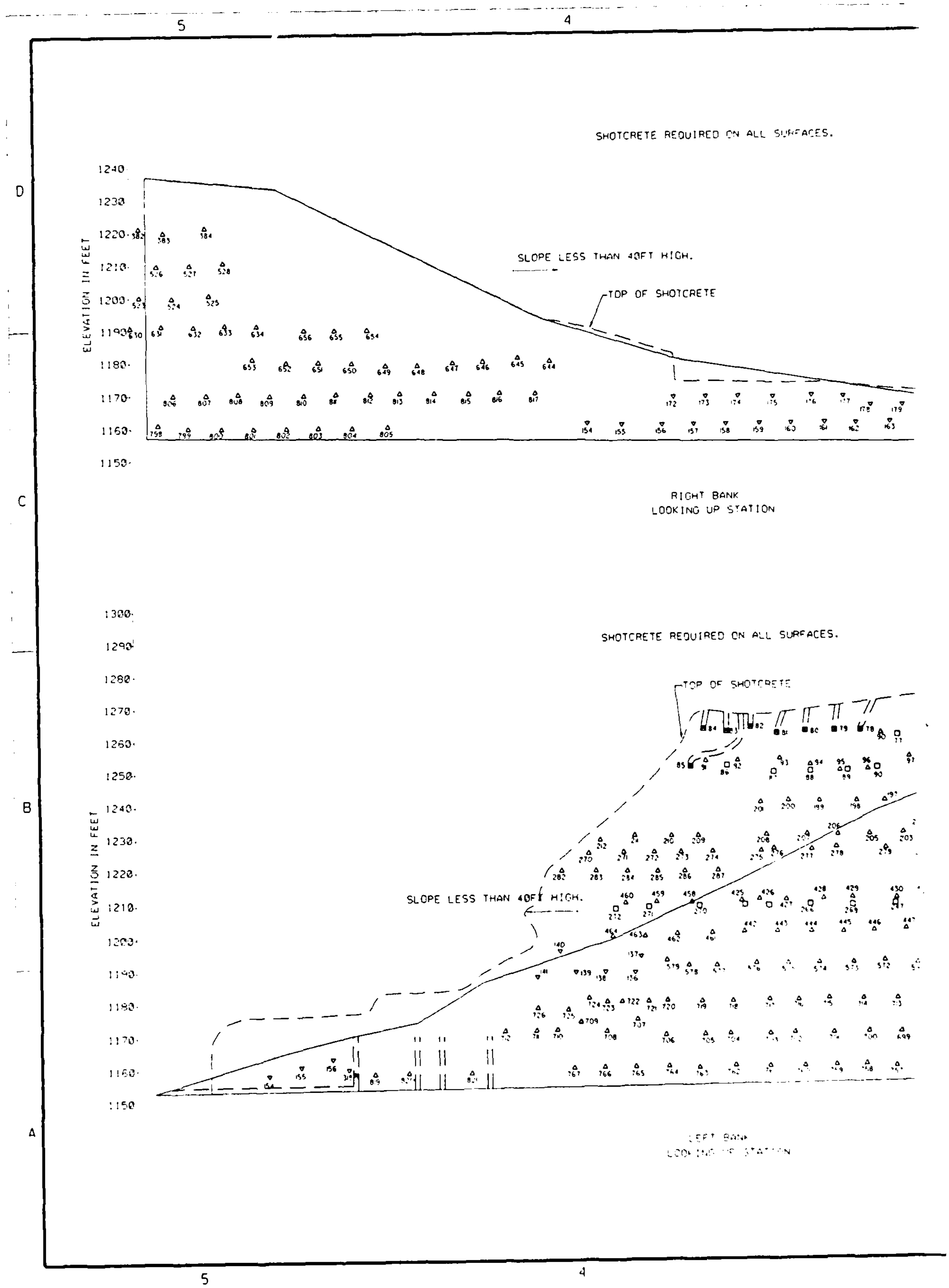
LEGEND

- DRAIN HOLES: 15' DEEP, 3" DIAMETER, ANGLED UP AT 5 DEGREES ON A 12' X 12' SQUARE PATTERN BEGINNING ON THE CENTERLINE OF EACH TUNNEL 14' ABOVE THE CROWN.
- PATTERN BOLTS: 10' LONG, ANGLED DOWN AT 5 DEGREES ON 10' X 10' STAGGERED PATTERN BEGINNING 12' ABOVE THE TUNNEL CROWN AND 5' LEFT AND RIGHT OF THE TUNNEL CENTERLINE.
- ROOF BOLTS: INSIDE TUNNEL 12' LONG ON 6' CENTERS RADIALLY [illegible] FROM CENTER AND ALONG TUNNEL AXES.
- CROWN BOLTS: [illegible] LONG ANGLED UP AT 20 DEGREES TO TUNNEL AXIS AS SHOWN ON DRAWING.
- DRAIN HOLES FULLY CASED WITH SLOTTED PVC PIPE.
- STRIP DRAINS.

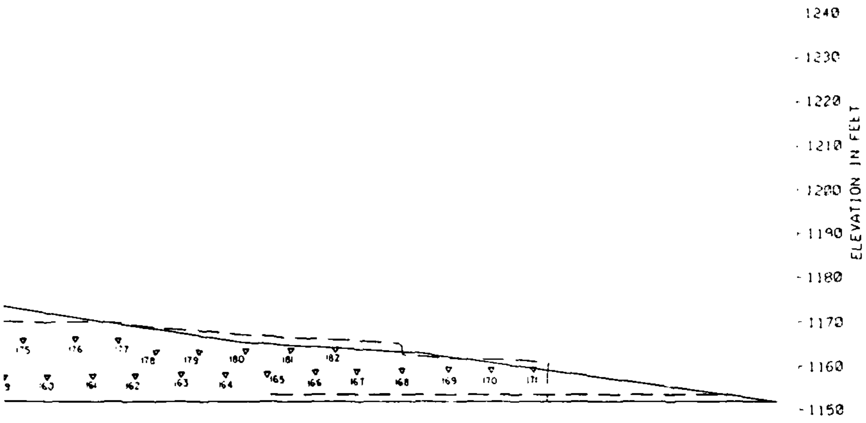
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

DOWNSTREAM PORTAL
ROCK SLOPE TREATMENT

01A-64/62


5
4
D
C
B
A
SHOTCRETE REQUIRED ON ALL SURFACES.
ELEVATION IN FEET
1240
1230
1220
1210
1200
1190
1180
1170
1160
1150
SLOPE LESS THAN 40FT HIGH.
TOP OF SHOTCRETE
RIGHT BANK
LOOKING UP STATION
SHOTCRETE REQUIRED ON ALL SURFACES.
ELEVATION IN FEET
1300
1290
1280
1270
1260
1250
1240
1230
1220
1210
1200
1190
1180
1170
1160
1150
TOP OF SHOTCRETE
SLOPE LESS THAN 40FT HIGH.
LEFT BANK
LOOKING UP STATION
5
4

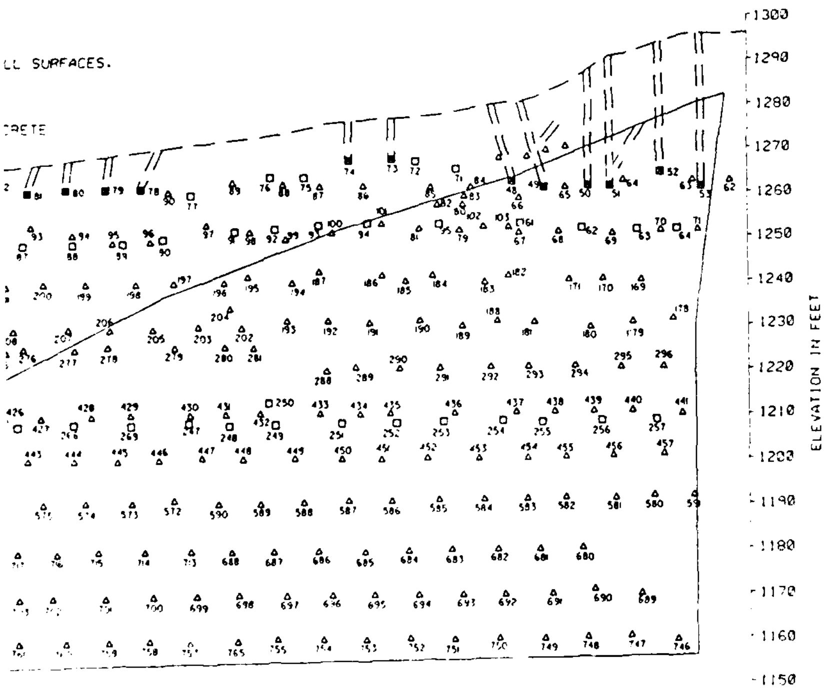
.L SURFACES.



ON

LL SURFACES.

CRETE



LEGEND

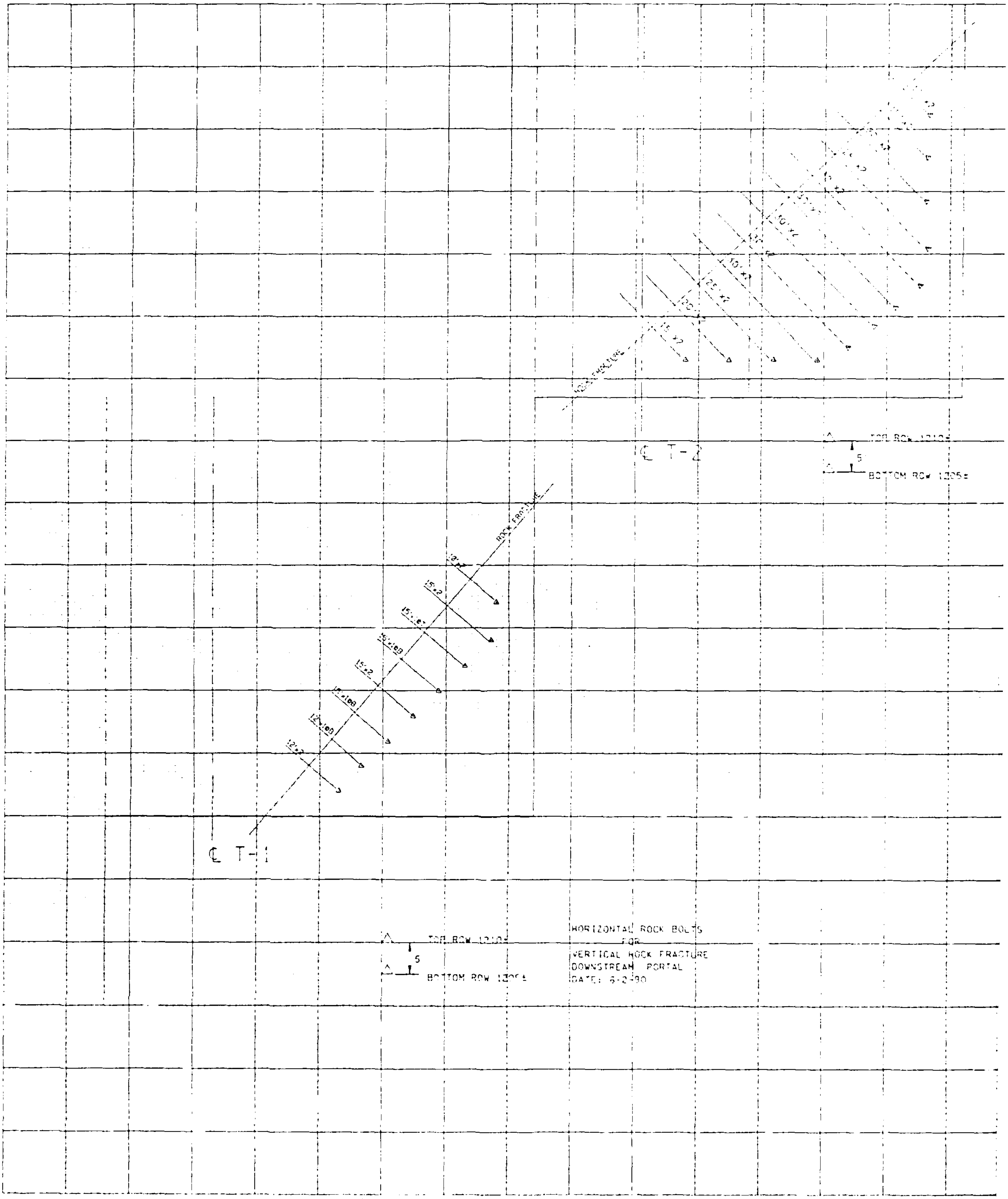
- □ DRAIN HOLES: 15' DEEP, 3" DIAMETER, ANGLED UP AT 5 DEGREES ON A 12' X 12' SQUARE PATTERN.
- △ PATTERN BOLTS: 10' LONG, ANGLED DOWN AT 5 DEGREES ON 10' X 10' STAGGERED PATTERN.
- ⊠ DRAIN HOLES FULLY CASED WITH SLOTTED PVC PIPE.
- ▽ ROCK DOWELS.
- = = STRIP DRAINS.

FOR NOTES SEE DRAWING OIA-64/58.

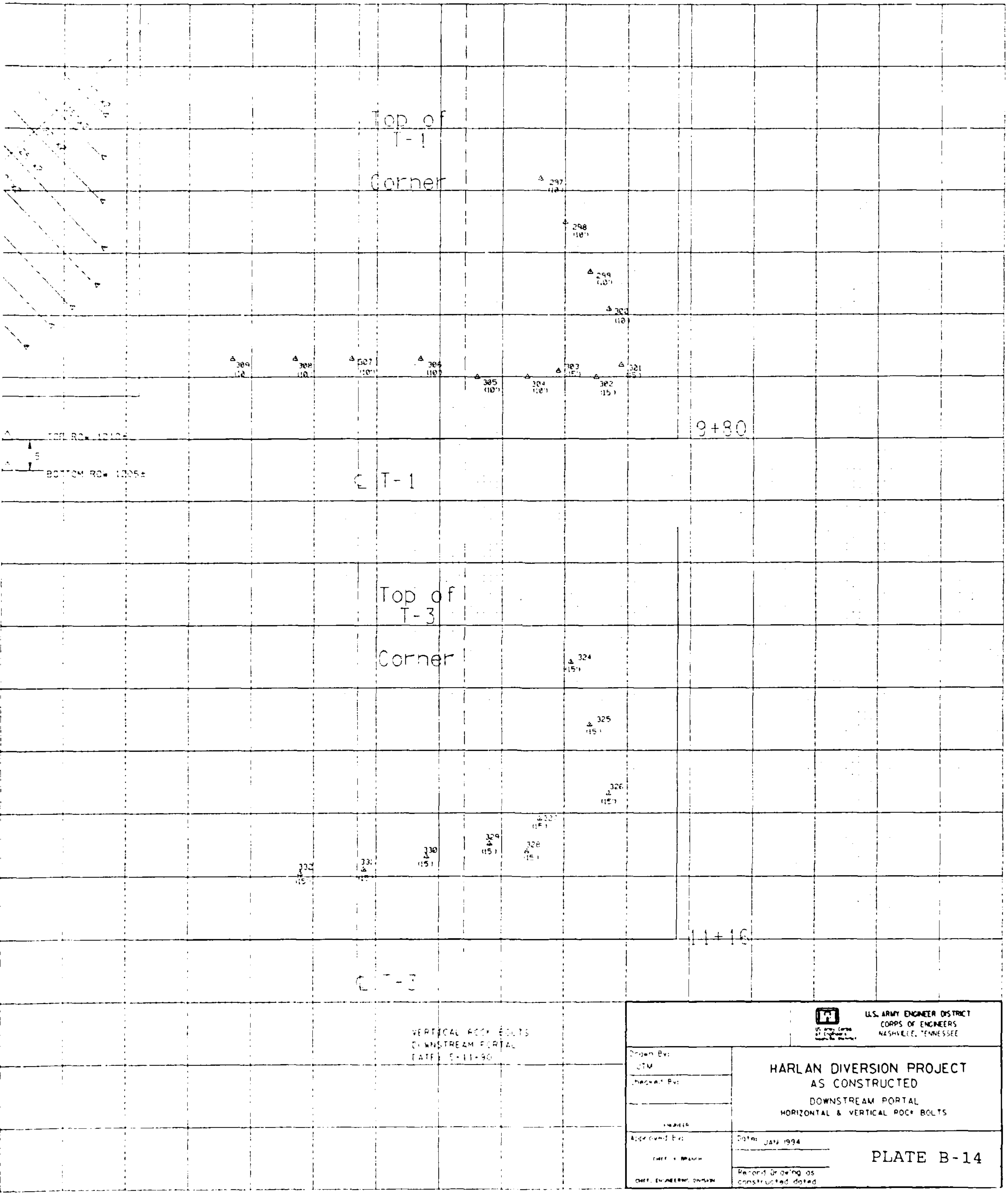
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

DOWNSTREAM PORTAL
SIDE SLOPE ROCK TREATMENT

OIA-64/70.2



ROCK FRACTURE
℄ T-2
℄ T-1
TOP ROW 1210±
BOTTOM ROW 1205±
5
HORIZONTAL ROCK BOLTS
FOR
VERTICAL ROCK FRACTURE
DOWNSTREAM PORTAL
DATE: 6-2-90



U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

Drawn By: JTM

Checked By:

Approved By:

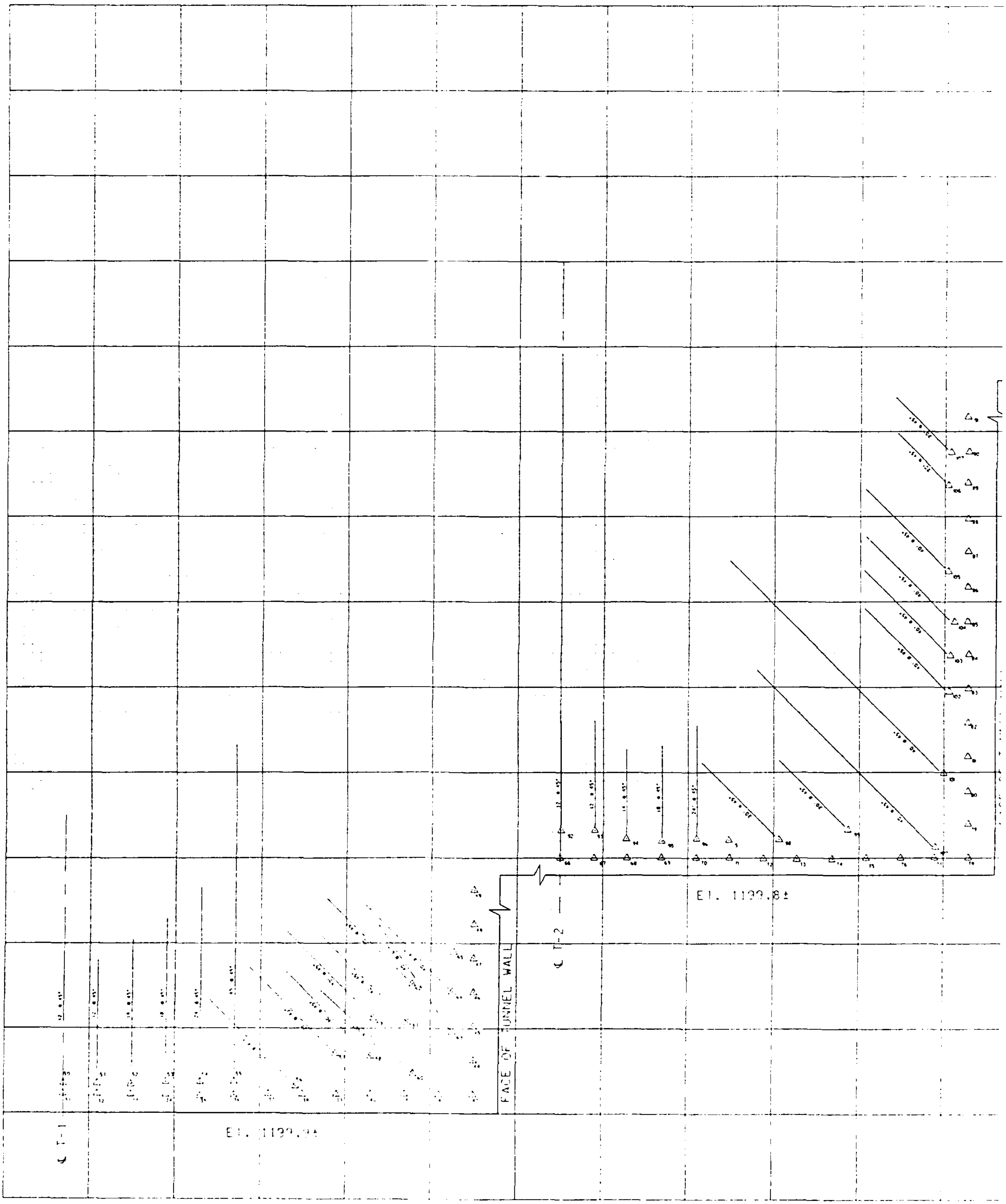
HARLAN DIVERSION PROJECT
AS CONSTRUCTED

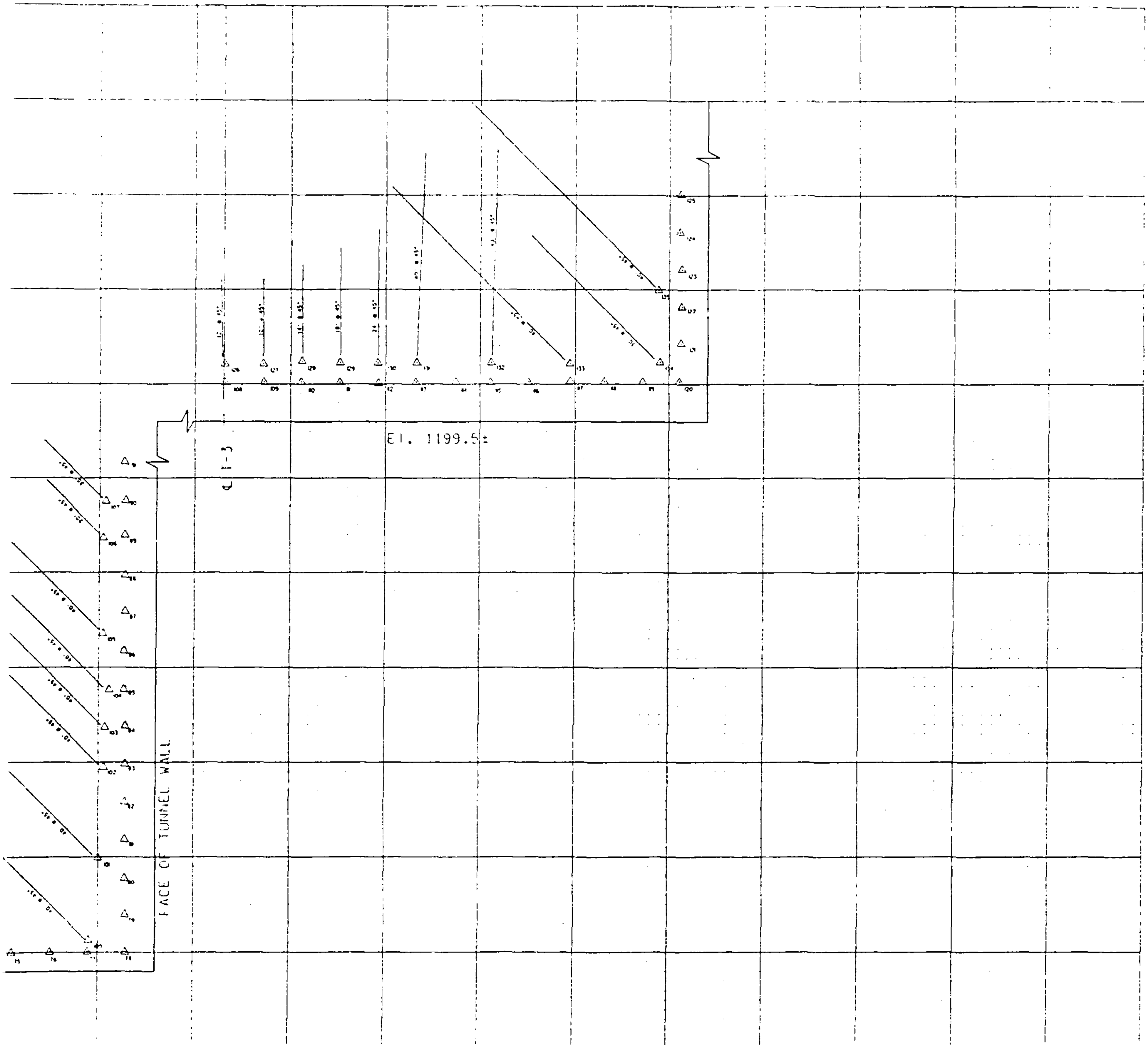
DOWNSTREAM PORTAL
HORIZONTAL & VERTICAL ROCK BOLTS

Date: JAN 1994

Record Drawing as constructed dated

PLATE B-14


FACE OF TUNNEL WALL
EL. 1139.8±
℄ T-2
℄ T-1
EL. 1139.8±



U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

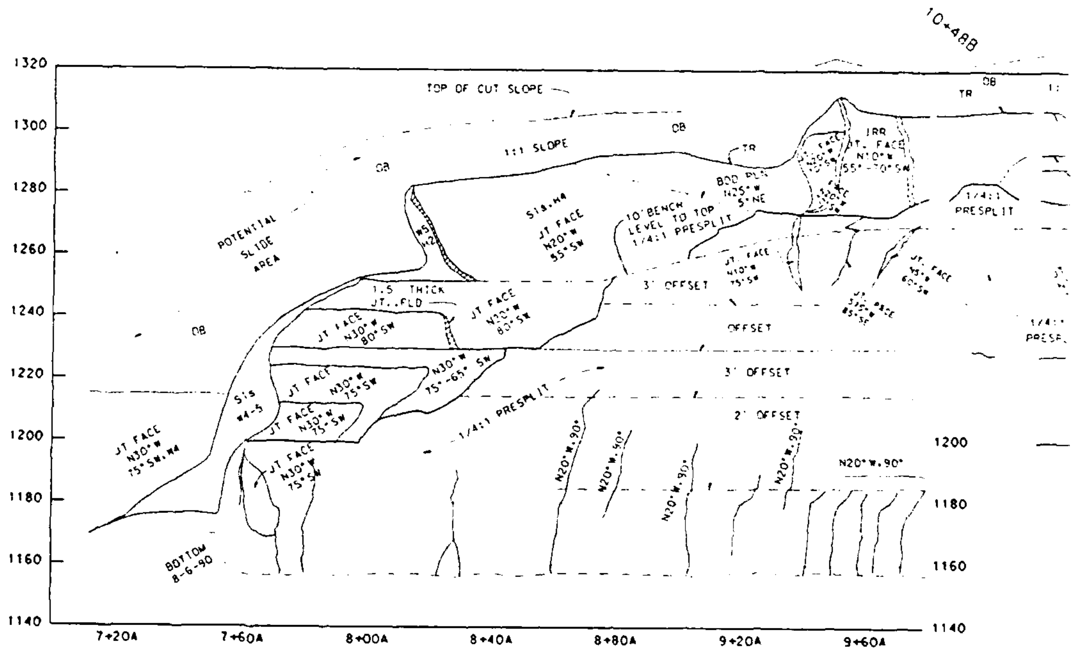
Drawn By: JTM	HARLAN DIVERSION PROJECT AS CONSTRUCTED DOWNSTREAM PORTAL AS BUILT DOWELS
Checked By:	
ENGINEER	
Approved By:	Date: JAN 1994
CHIEF, BRANCH	Scale: NOT TO SCALE
CHIEF, ENGINEERING DIVISION	Record Drawing: constructed dated

PLATE B-15

5 4

D

C



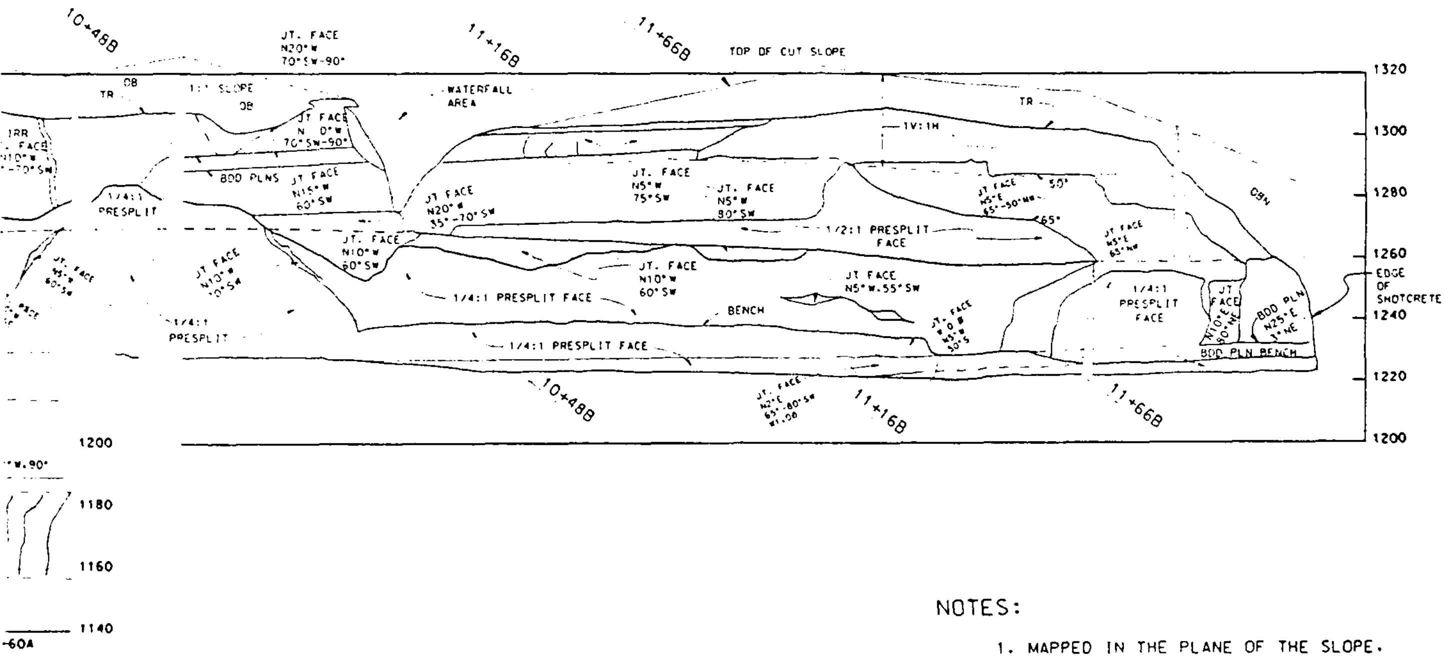
10+48B
1320
1300
1280
1260
1240
1220
1200
1180
1160
1140
TOP OF CUT SLOPE
1:1 SLOPE
OB
TR
POTENTIAL SLIDE AREA
S1s,W4
JT FACE N20°W 55°SW
10' BENCH LEVEL TO TOP 1/4:1 PRESPLIT
BDD PLN N25°W 5°NE
IRR JT. FACE N10°W 55°-70°SW
1/4:1 PRESPLIT
1.5 THICK JT. FLD
JT FACE N20°W 80°SW
JT FACE N30°W 80°SW
3' OFFSET
JT. FACE N10°W 75°SW
OFFSET
3' OFFSET
2' OFFSET
JT FACE N30°W 75°SW
N30°W 75°-65° SW
S1s W4-5
JT FACE N30°W 75°SW,W4
JT FACE N30°W 75°SW
1/4:1 PRESPLIT
N20°W,90°
N20°W,90°
BOTTOM 8-6-90
7+20A
7+60A
8+00A
8+40A
8+80A
9+20A
9+60A
1200
1180
1160
1140

B

A

5 4

REV.	DESCRIPTION	DATE	BY	APPROVED



NOTES:

1. MAPPED IN THE PLANE OF THE SLOPE. EXCEPT FOR HORZONITAL BENCHES WHICH ARE NOT SHOWN.
2. ROCK REINFORCEMENT AND DRAINAGE NOT SHOWN.

Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

Drawn By: C.A.G.

Checked By: P.R.

LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION TUNNELS

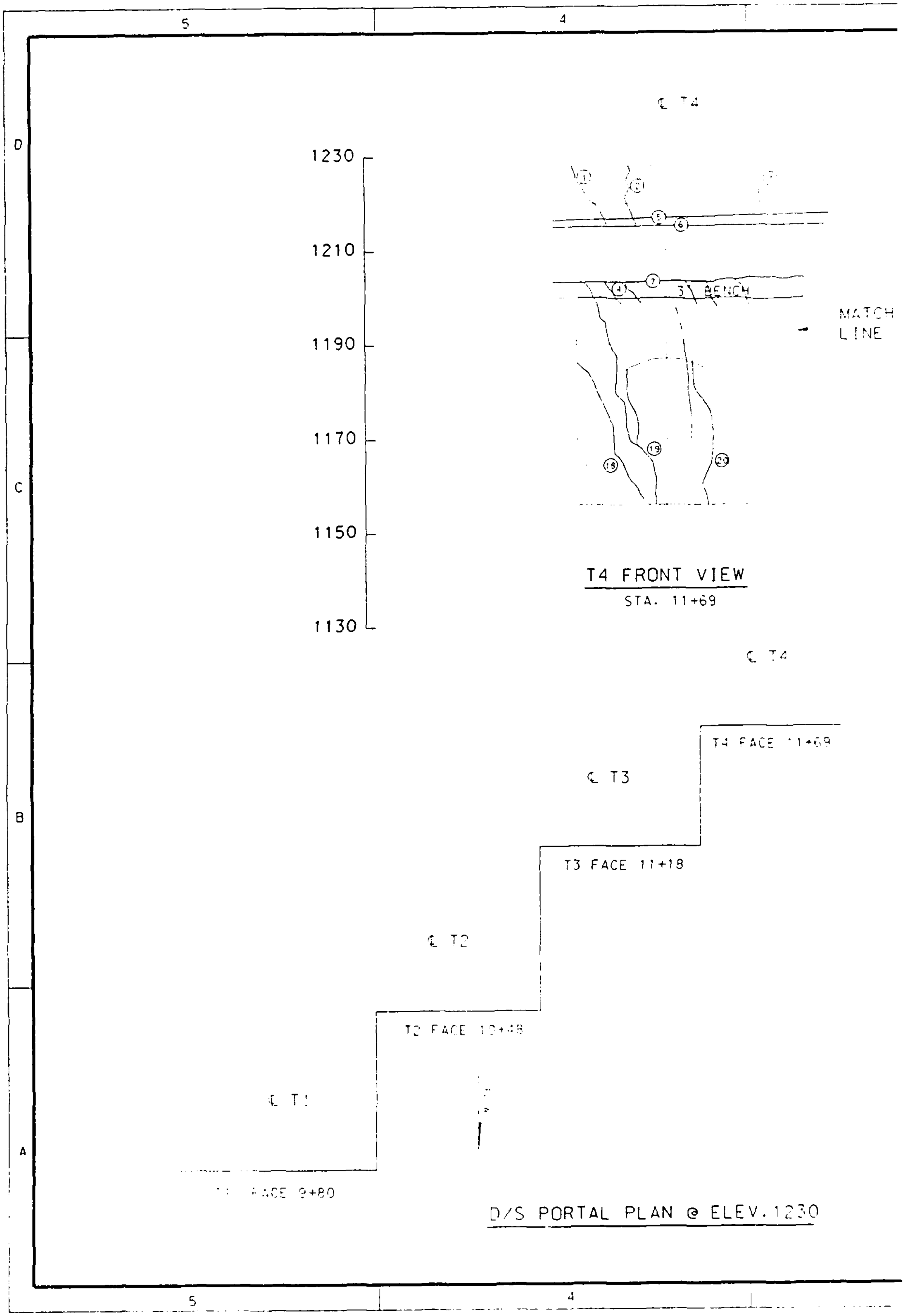
DOWNSTREAM PORTAL AREA
GEOLOGIC MAP OF SURFACE SLOPES

Approved By:

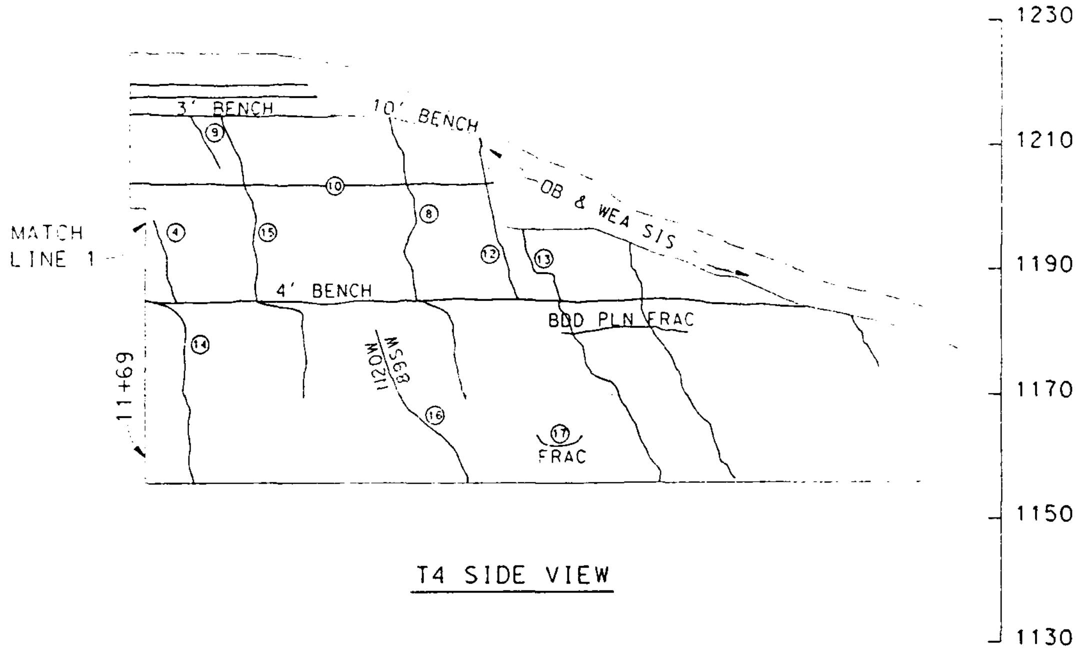
COMPUTER SOILS AIDED SECTION DESIGN & DRAFTING

Drawing Number: Q1A-4386

PLATE B-16



5
4
D
C
B
A
1230
1210
1190
1170
1150
1130
℄ T4
BENCH
MATCH LINE
T4 FRONT VIEW
STA. 11+69
℄ T4
T4 FACE 11+69
℄ T3
T3 FACE 11+18
℄ T2
T2 FACE 10+48
℄ T1
FACE 9+80
D/S PORTAL PLAN @ ELEV.1230



T4 SIDE VIEW

T4 JOINT DESCRIPTIONS

1. Jt.N20°E 65°-75°W-NW
2. Jt.N20°E 80°NW
3. Jt.N10°E 75°SE
4. jts. N15°W 75°SW
5. Bdd pln N70°W 2°NE
6. Bdd pln N70°W 2°NE
7. Bdd pln 0°ø
8. Jt. N10°E 90°-80°NW
9. Jt. N10°E 90° 0ø
10. Bdd plns.hor.0ø
11. Jt. N10°E 90°ø
12. Jt.N10°E 80°-70°NW 0ø
13. Jt.N10°E 90° 0ø
14. Jt.N10°E 90° 0ø
15. Jt.N12°E 90° 0ø
16. Jt.N20°W 89°SW
17. Blast Frac
18. Jt.N5°E 60°W 90° 0ø
19. Jt.N10°E 70°-[illegible]°NW 0ø
20. Jt.N15°E 90° 0ø

EW

LEV.1230

20' 0 20'

Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

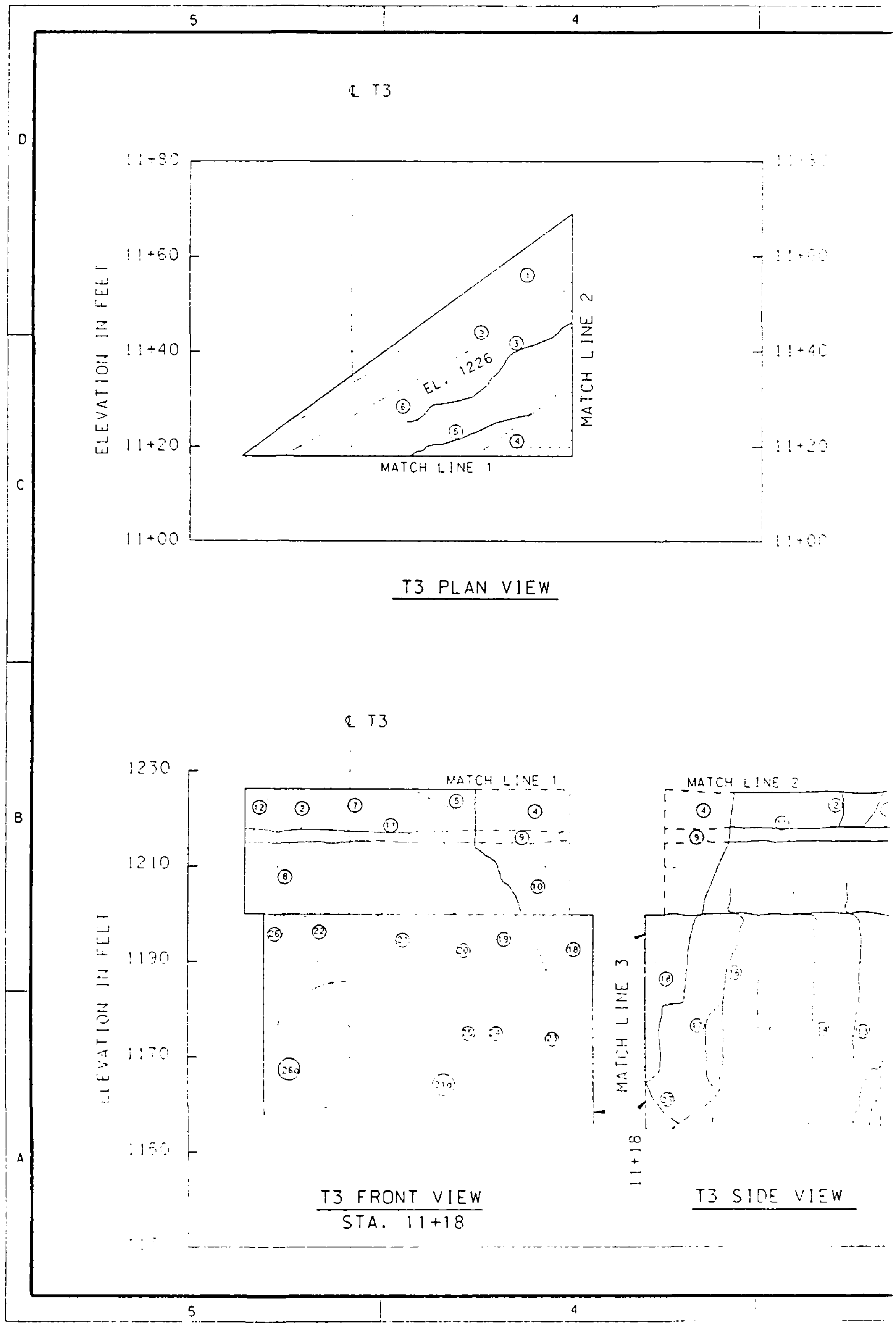
Checked By: P.R.

LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION TUNNELS
DOWNSTREAM PORTAL–TUNNEL 4
GEOLOGIC MAP

Date: FEB 1994

Drawing Number: Q1A-4387

PLATE B-17



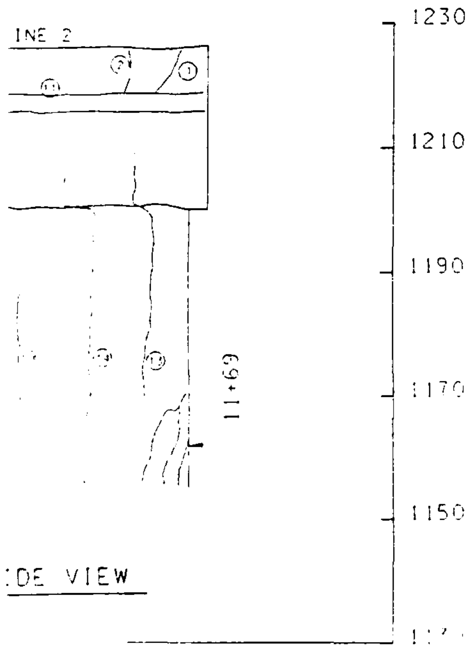
5
4
D
C
B
A
℄ T3
ELEVATION IN FEET
11+80
11+60
11+40
11+20
11+00
EL. 1226
MATCH LINE 1
MATCH LINE 2
T3 PLAN VIEW
℄ T3
1230
1210
1190
1170
1150
MATCH LINE 1
MATCH LINE 2
MATCH LINE 3
11+18
T3 FRONT VIEW
STA. 11+18
T3 SIDE VIEW

T-3 JOINT DESCRIPTIONS

1. JT N20°E 75°NW-90°..04'(op½"-3/4" by blast),ti
2. JT N20°E 75°NW-90°..04'(op½"-3/4" by blast),ti
3. Irreg.BF
4. Jt face N10°E 70°NW
5. Jt.N20°E.60°NW (cly si)
6. Bdd pln.N20°W 3°NE
7. Jt N20°E 80°NW
8. Jt.N20°E 90.ti
9. Blast fractured face
10. Jt face.N5E.80NW-90°
11. Bdd pln.0ø.cly si
12. Jt face.N20°E 75°NW
13. Jt. N5°E 75°NW-90°(op½"-3/4" by blast)
14. Jt.N10°E 90°.ti
15. Jt N20°W 90°.ti
16. Jt.N10°E 90°.ti
17. Jt.N10°W 90°.ti
18. Jt face N20°E 70°NW 90°.ti

(19)(20)(21) Jt.N5°E 90°.ti

22. Jt.N10°W70°SW.ti
23. Jt.N15°E 90° .04
24. Jt. N10°W 85°SW.ti
25. Jt. N15°E 80°NW.ti
26. Jt. N0°E 80°W.ti
27. Jt. N65°E 75°SE



Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENN.

Drawn By: CAG
Checked By: PF

KENTUCKY AND TENNESSEE
UPPER CUMBERLAND RIVER BASIN
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION TUNNELS
DOWNSTREAM PORTAL-T3 CORNER
GEOLOGIC MAPS

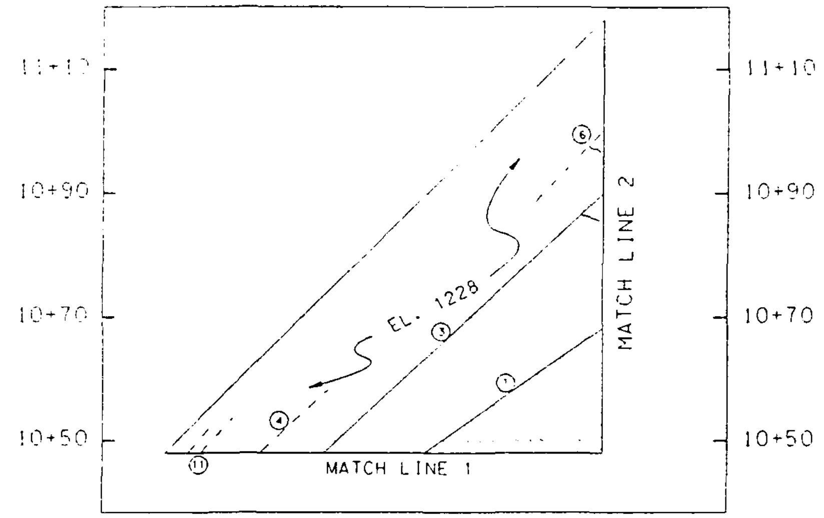
Date: FEB 1994

Record Drawing as constructed dated

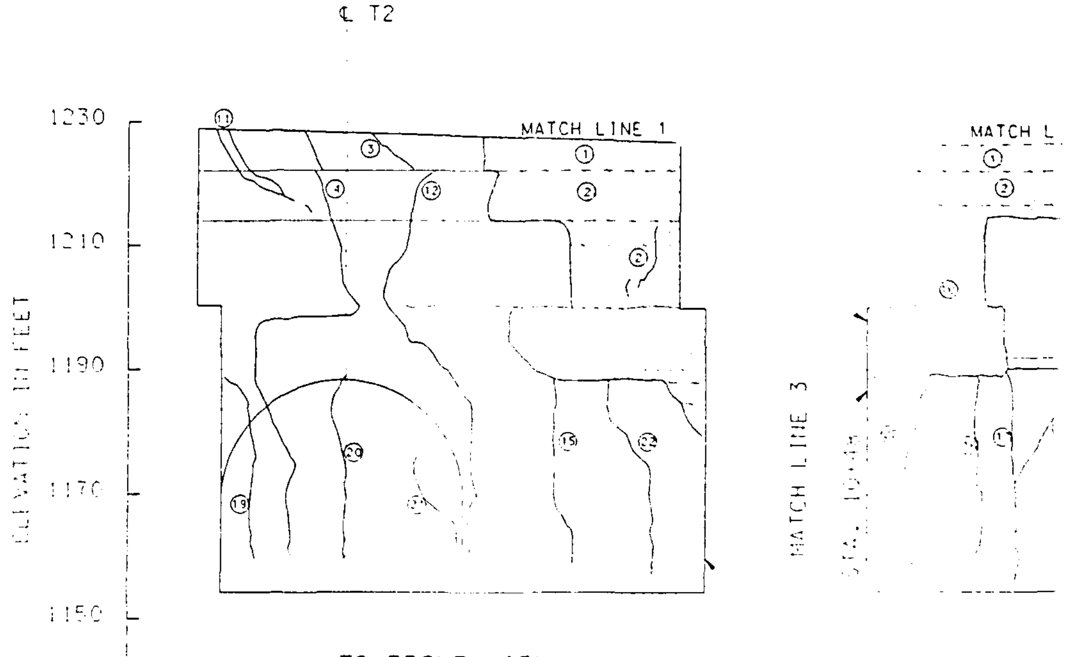
Drawing Number: Q1A-4388

Computer Services Aided Section Design and Drafting

PLATE B-18



T2 PLAN VIEW

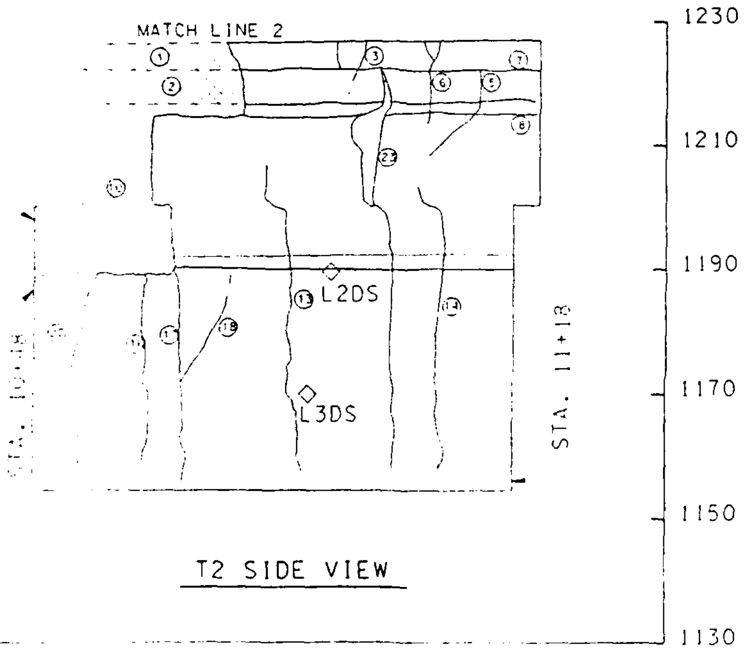


T2 FRONT VIEW
STA. 10+48

T2

T-2 JOINT DESCRIPTIONS

1. Blast fractured.irr. N20°E
2. Jt Face N10°E 90°
3. Jt.N5°E65°NW
4. Jt.N2°E 90°
5. Jt.N10°E 90°(op 1" by blast)
6. Jt.N10°E 90°(op 1" by blast)
7. Bdd pln.hor
8. Bdd pln.hor
10. Jt face N15°E 90°
11. Jts. N20°E 30°NW
12. Jt.N0°E V
13. 14. Jts.N10°E 90°
15. Jt.N10°W 80°SW
16. Jt.N10°E 90°
17. Jt.N20°W 80°SW
18. Jt
19. Jt.N24°E 84°NE
20. Jt.N25°E 81°SE
21. Jt.N35°E 85°SE
22. Jt.face N20°E 90°-75°NW



T2 SIDE VIEW

LEGEND

L3DS ◇ LOAD CELL

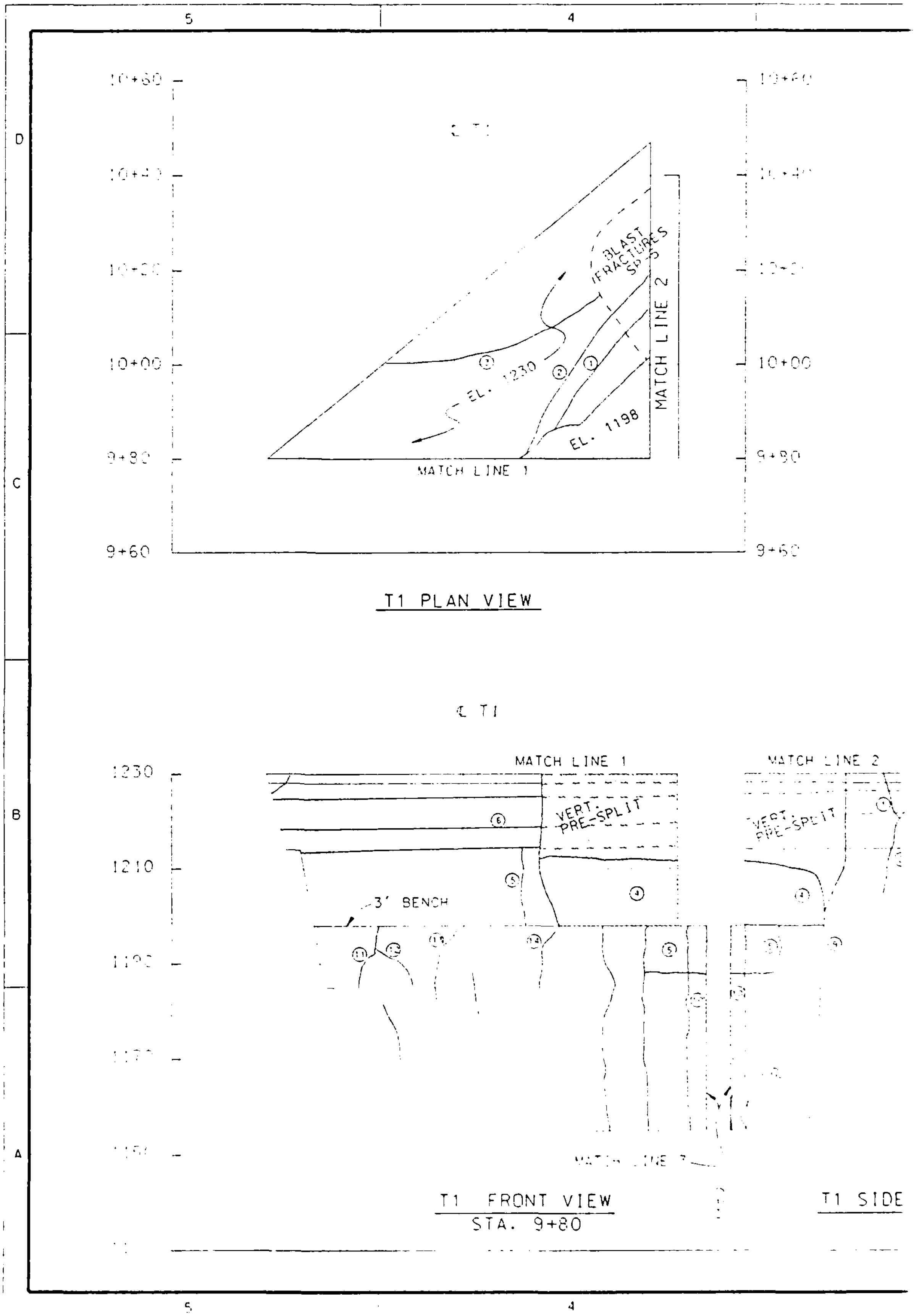
Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION TUNNELS
DOWNSTREAM PORTAL-T2 CORNER
GEOLOGIC MAPS

Date: FEB 1994

Q1A-4389



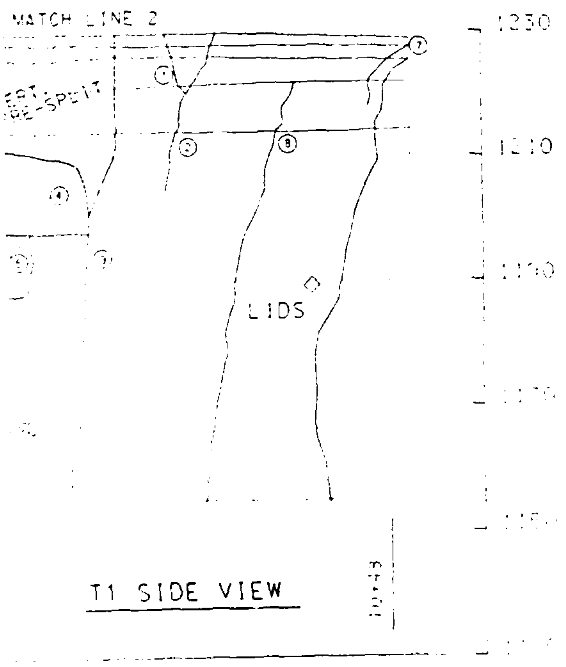
5
4
D
C
B
A
10+60
10+40
10+20
10+00
9+80
9+60
BLAST FRACTURES SP-5
MATCH LINE 2
EL. 1230
EL. 1198
MATCH LINE 1
T1 PLAN VIEW
℄ T1
1230
1210
MATCH LINE 1
MATCH LINE 2
VERT. PRE-SPLIT
3' BENCH
T1 FRONT VIEW
STA. 9+80
T1 SIDE

T1 JOINT DESCRIPTIONS

1. Jt.N15°W 90°..03(open¾" by blast.
2. Jt.N15°W 90°..03(open¾" by blast)
3. Blast fractured.open¼"
4. Jt.N5°E 60°SE-70°NW
6. Bdd pln.N80°W 3°NE
7. Jts.N20°E20°-30°NW
8. Jt.N10°W 80°SW
9. Jt.N10°E 90°-80°NW
10. Jt face. N10°E 90°
11. Jt.N10°E 70°NW
12. Jt.N10°E 30°NW
13. Jt N-S 90°-80°SW
14. Jt N10°E 90°
15. Jt.N15°E 90°
16. Jt.N5°E 84°NW

LEGEND

LIDS ◇ LOAD CELL



T1 SIDE VIEW

20' 0 20'

Graphic Scale

U.S. ARMY ENGINEER DISTRICT, CORPS OF ENGINEERS, NASHVILLE, TENNESSEE

UPPER CUMBERLAND RIVER BASIN KENTUCKY AND TENNESSEE

LOCAL PROTECTION PROJECT

HARLAN, KENTUCKY

DIVERSION TUNNELS

DOWNSTREAM PORTAL-T1 CORNER

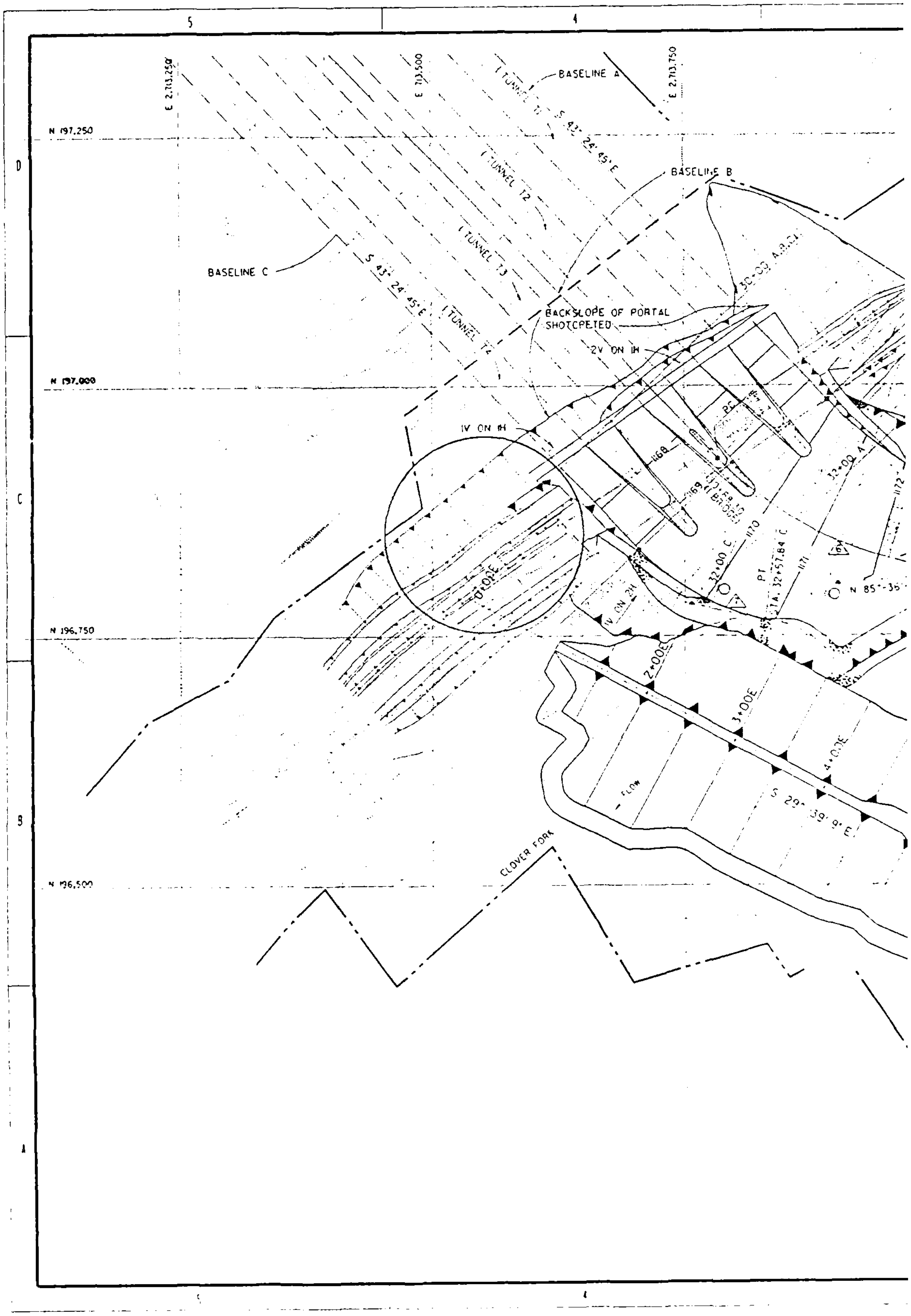
GEOLOGIC MAPS

FEB 1994

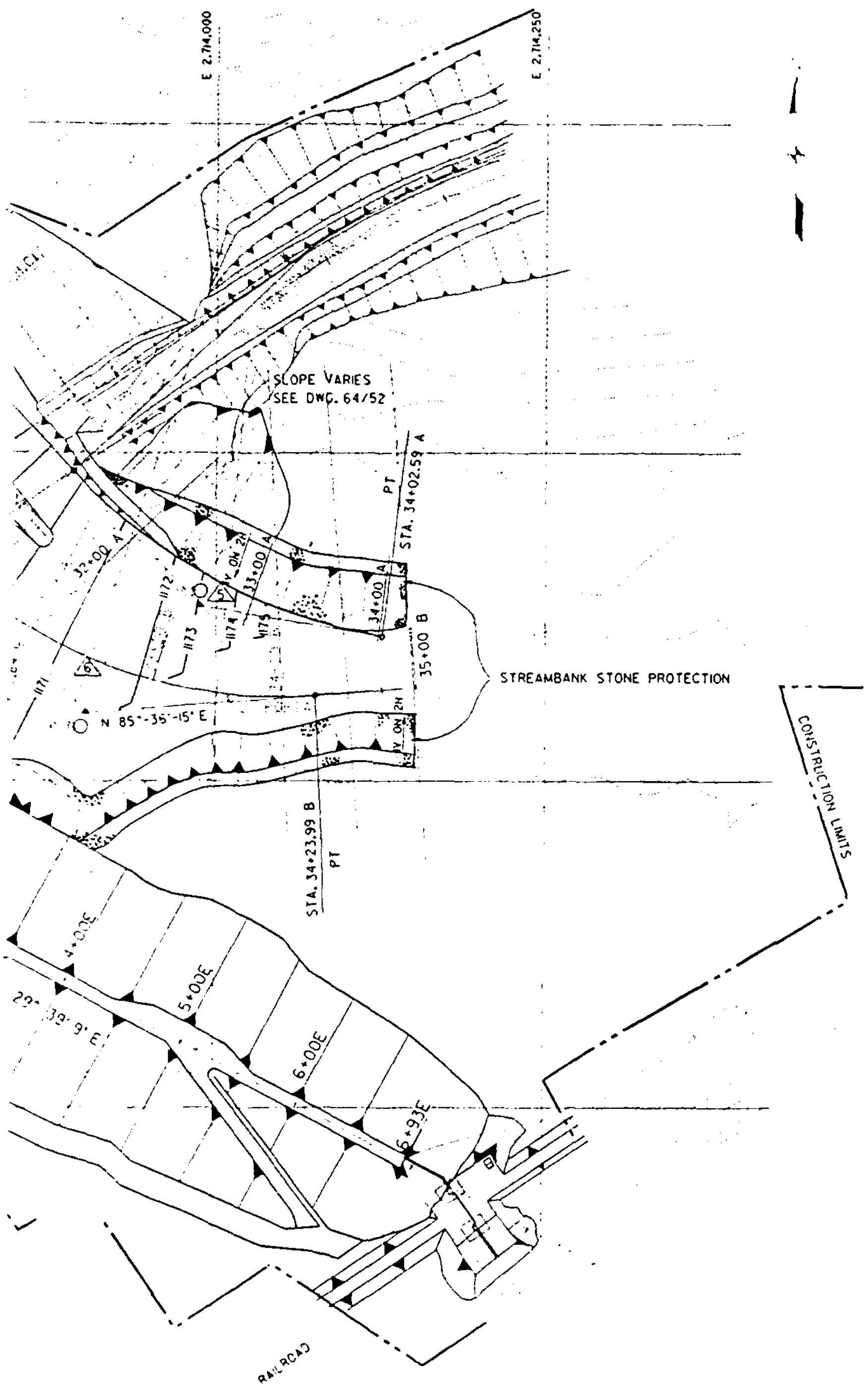
Q1A-4390

Appendix C - Upstream Portal

Plate No.	Drawing No.	Description
C-1	Q1A-64/51.2	General Plan
C-2	Q1A-64/32.1	Boring Plan
C-3	Q1A-64/33.2	Geologic Section C-C
C-4	Q1A-64/34.1	Geologic Section D-D
C-5	Q1A-64/35.1	Geologic Section E-E
C-6	Q1A-64/36.1	Geologic Section F-F
C-7	Q1A-64/3[illegible].2	Geologic Section G-G
C-8	Q1A-64/38.2	Geologic Section H-H
C-9	Q1A-64/54	Cross Sections
C-10	Q1A-4/391	Back-Slope Cross-Sections
C-11	Q1A-64/103.1	Nosing Plan
C-12	Q1A-64/104.1	Nosing Sections
C-13	Q1A-64/106.1	Nosing and Base Slab Detail
C-14	Q1A-59.3	Rock Slope Treatment
C-15	Q1A-64/58.1	Rock Slope Treatment
C-16	-------	Nosing 1 Reinforcement
C-17	-------	Nosing 2 Reinforcement
C-18	-------	Nosing 3 Reinforcement
C-19	Q1A-4/[illegible]93	Geologic Map
C-20	Q1A-4/392	Nosing Surface Map
C-21	Q1A-4/394	Nosing 1 Map
C-22	Q1A-4/395	Nosing 2 Map
C-23	Q1A-4/396	Nosing 3 Map



5
4
D
C
B
A
E 2,713,250
E 2,713,500
E 2,713,750
N 197,250
N 197,000
N 196,750
N 196,500
BASELINE A
BASELINE B
BASELINE C
S 43° 24' 45" E
BACKSLOPE OF PORTAL
SHOTCRETED
2V ON 1H
1V ON 1H
1V ON 2H
32+00 C
32+00 A
0+00E
2+00E
3+00E
4+00E
FLOW
CLOVER FORK



CURVE DATA

CURVE 5 BASELINE A	CURVE 6 BASELINE B	CURVE 7 BASELINE C
PI 5 STA. 32+72.41 A	PI 6 STA. 32+72.41 B	PI 7 STA. 31+87.27 C
N 196,883.77	N 196,801.98	N 196,781.95
E 2,713,987.84	E 2,713,901.40	E 2,713,756.54
△ 37°-00'-00"	△ 51°-00'-00"	△ 34°-00'-00"
D 13.69°	D 15.62°	D 23.36°
L 270.18 FT.	L 326.58 FT.	L 145.31 FT.
T 140.00 FT.	T 175.00 FT.	T 75.00 FT.
R 418.42 FT.	R 366.90 FT.	R 245.31 FT.

NOTES:

1. FOR GENERAL NOTES SEE DWG. 64/2.
2. FOR DETAILED GEOMETRY OF PORTAL NOSES, SEE DWGS. 64/103 AND 64/104.
3. FOR DETAILS OF EMBANKMENT, SEE DWG. 64/74.
4. FOR DETAILS OF CLOSURE STRUCTURE, SEE DWG. 64/87.
5. FOR ROAD AND BRIDGE DETAILS SEE SEPERATE FOLIO.

Revisions	Date	Description	By	Checked
2	6-30-89	CHANGED CONSTRUCTION LIMITS, ADDED SLOPE DATA & NOTE 5	B.F.	D.J.
1	5-3-89	CONFORMING TO REVIEW COMMENTS	[illegible]	P.E.B.

50 0 50
Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

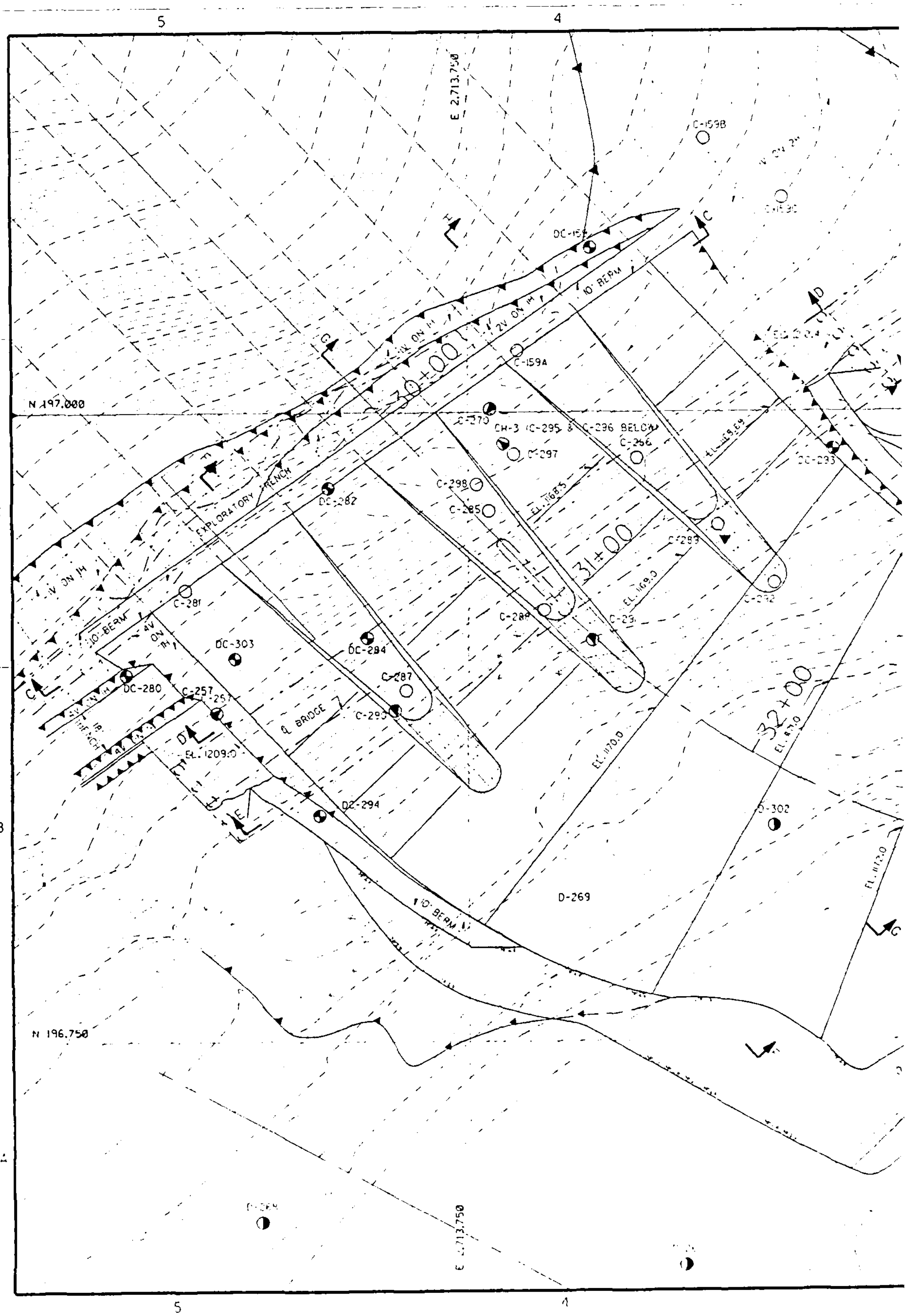
Designed By: P.E.B.
Checked By: P.E.B.

UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION
GENERAL PLAN
UPSTREAM PORTAL

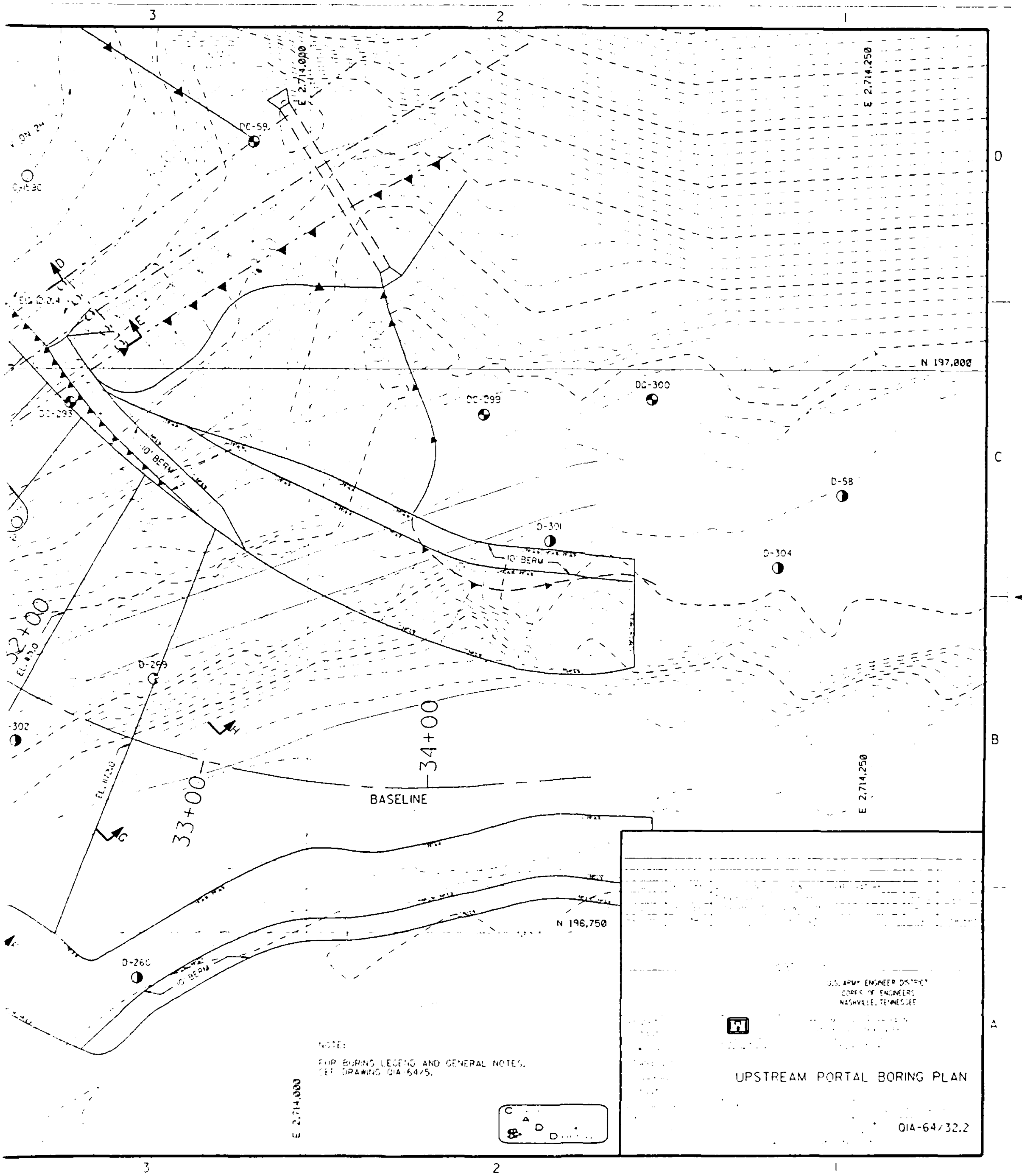
Date: FEB 1989
Scale: 1" = 50
Drawing Number: 01A-64/51.2

Record Drawing as Constructed Dated

Computer Aided Design & Drafting

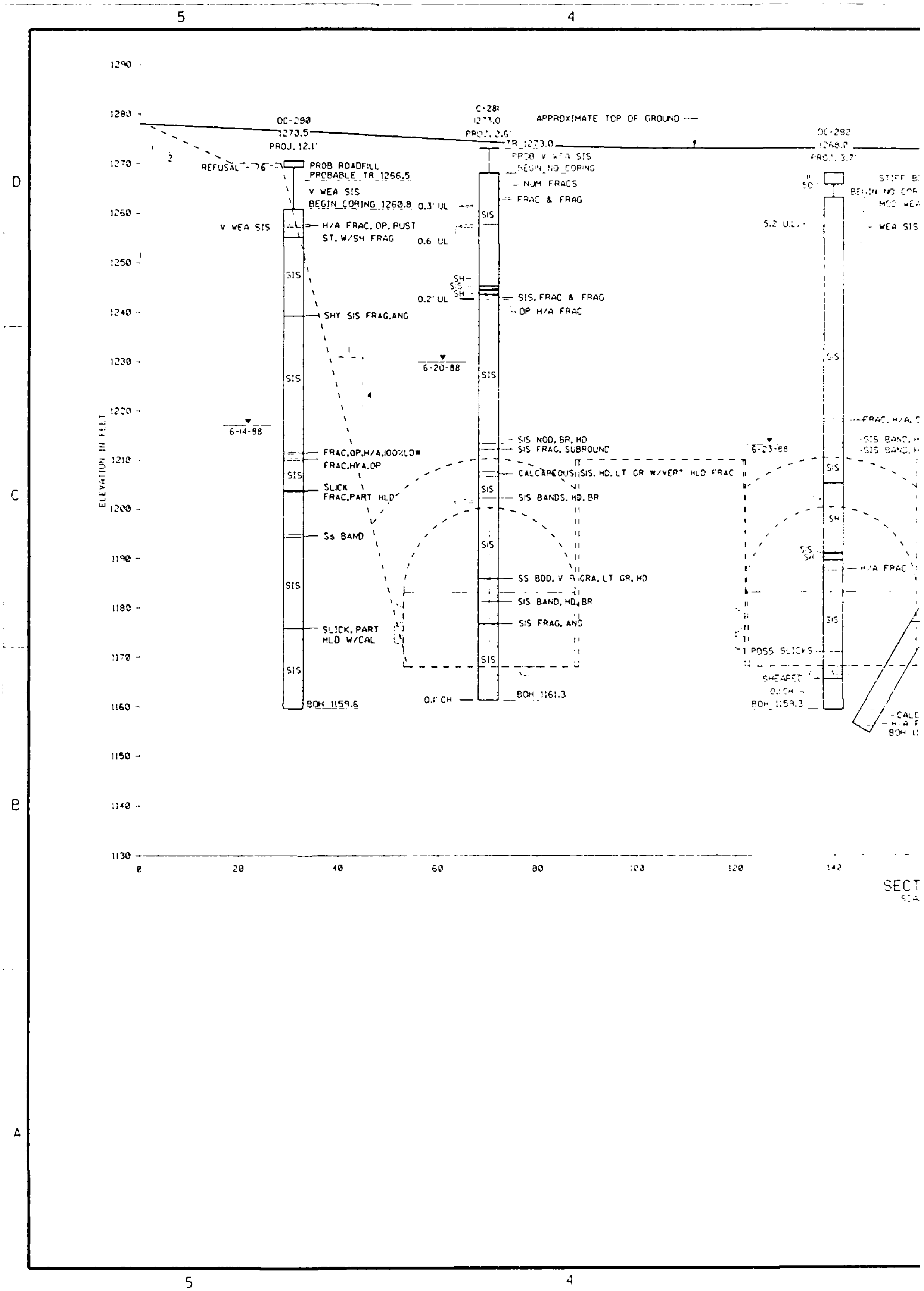


5
4
D
C
B
E 2,713,750
N 197,000
N 196,750
C-159B
DC-159
C-159A
C-270
CH-3 (C-295 & C-296 BELOW)
C-297
C-266
C-298
C-285
DC-282
C-281
DC-303
DC-284
C-287
C-293
DC-280
C-257
DC-294
C-288
C-289
C-292
DC-293
D-302
D-269
EXPLORATORY TRENCH
10' BERM
2V ON 1H
30+00
31+00
32+00
EL. 1209.0
EL. 1168.5
EL. 1169.0
EL. 1170.0
EL. 1172.0
℄ BRIDGE

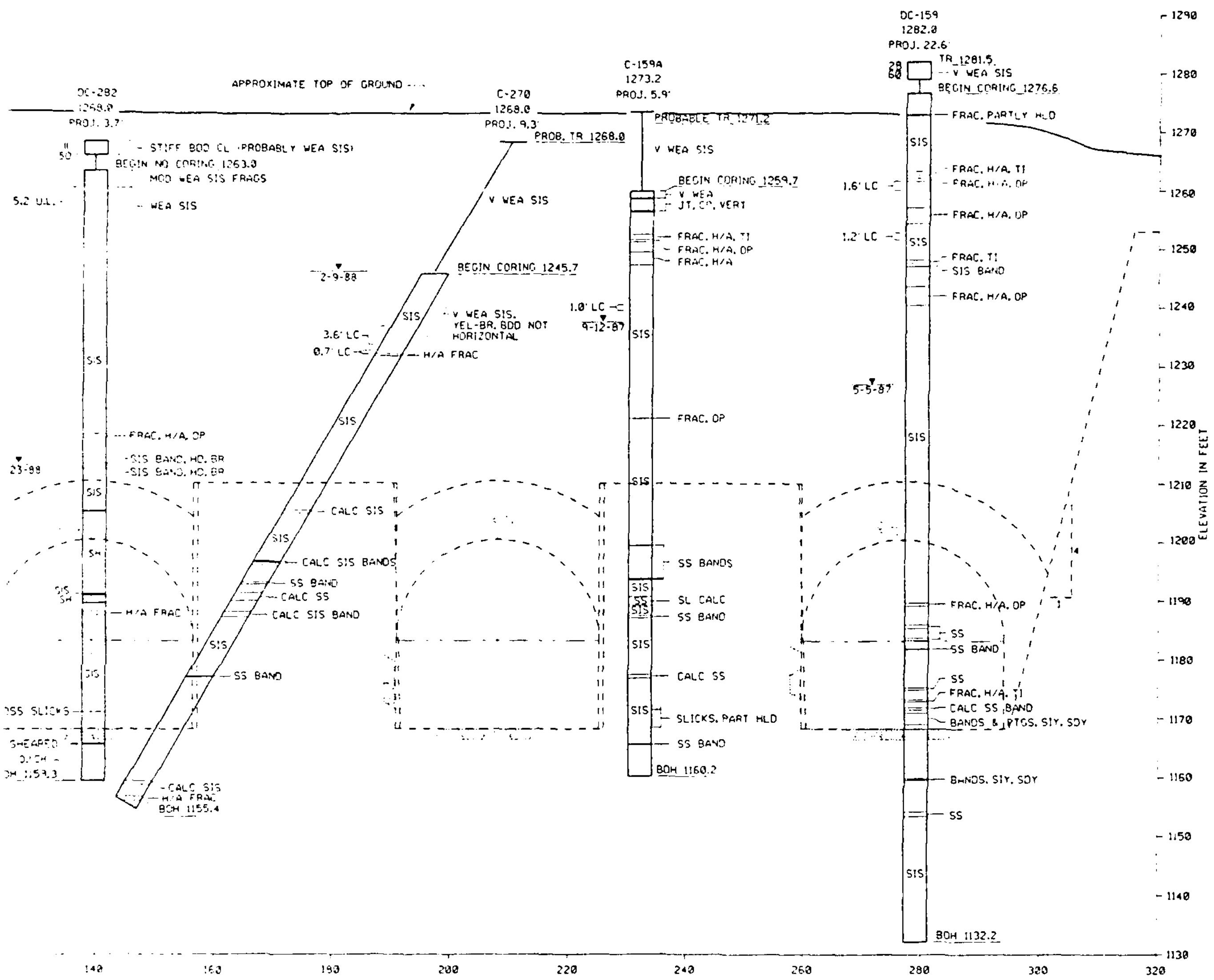


E 2,714,000
E 2,714,250
DC-59
DC-293
DC-299
DC-300
D-58
D-301
D-304
D-299
-302
D-260
N 197,000
N 196,750
10' BERM
10' BERM
10' BERM
32+00
33+00
34+00
BASELINE
NOTE:
FOR BORING LEGEND AND GENERAL NOTES, SEE DRAWING OIA-64/5.
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE
UPSTREAM PORTAL BORING PLAN
OIA-64/32.2

PLATE C-2



APPROXIMATE TOP OF GROUND
OC-280
1273.5
PROJ. 12.1'
C-281
1273.0
PROJ. 2.6'
TR 1273.0
OC-282
1268.0
PROJ. 3.7'
REFUSAL
PROB ROADFILL
PROBABLE TR 1266.5
V WEA SIS
BEGIN CORING 1260.8
H/A FRAC, OP, RUST
ST, W/SH FRAG
V WEA SIS
SHY SIS FRAG, ANG
FRAC, OP, H/A, 100%LOW
FRAC, H/A, OP
SLICK
FRAC, PART HLD
Ss BAND
SLICK, PART
HLD W/CAL
BOH 1159.6
6-14-88
PROB V WEA SIS
BEGIN NO CORING
NUM FRACS
FRAC & FRAG
0.3' UL
0.6 UL
0.2' UL
SIS, FRAC & FRAG
OP H/A FRAC
6-20-88
SIS NOD, BR, HD
SIS FRAG, SUBROUND
CALCAREOUS SIS, HD, LT GR W/VERT HLD FRAC
SIS BANDS, HD, BR
SS BDD, V F GRA, LT GR, HD
SIS BAND, HD, BR
SIS FRAG, ANG
0.1' CH
BOH 1161.3
6-23-88
5.2 U.L.
POSS SLICKS
SHEARED
0.1' CH
BOH 1159.3
STIFF
BEGIN NO COR
MOD WEA
WEA SIS
FRAC, H/A
SIS BAND
SIS BAND
H/A FRAC
ELEVATION IN FEET
1290
1280
1270
1260
1250
1240
1230
1220
1210
1200
1190
1180
1170
1160
1150
1140
1130
0
20
40
60
80
100
120
140
SECT



SECTION C-C

NOTES:

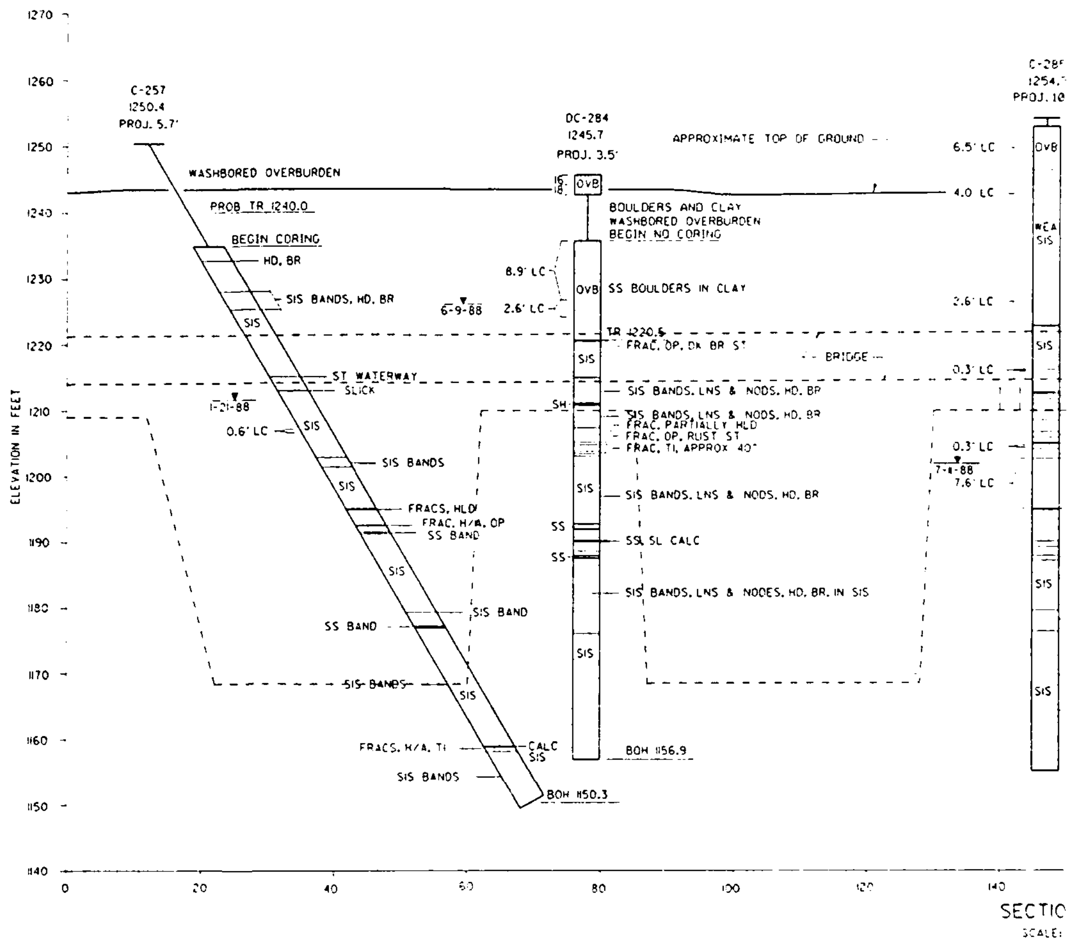
1. FOR LOCATIONS OF SECTIONS AND BORING PLAN, SEE DRAWING 01A-64/32.
2. FOR DETAILED LOGS OF BORINGS, SEE DRAWINGS 01A-64/7 THROUGH 01A-64/29.
3. FOR GENERAL NOTES, SEE DRAWING 01A-64/7.

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

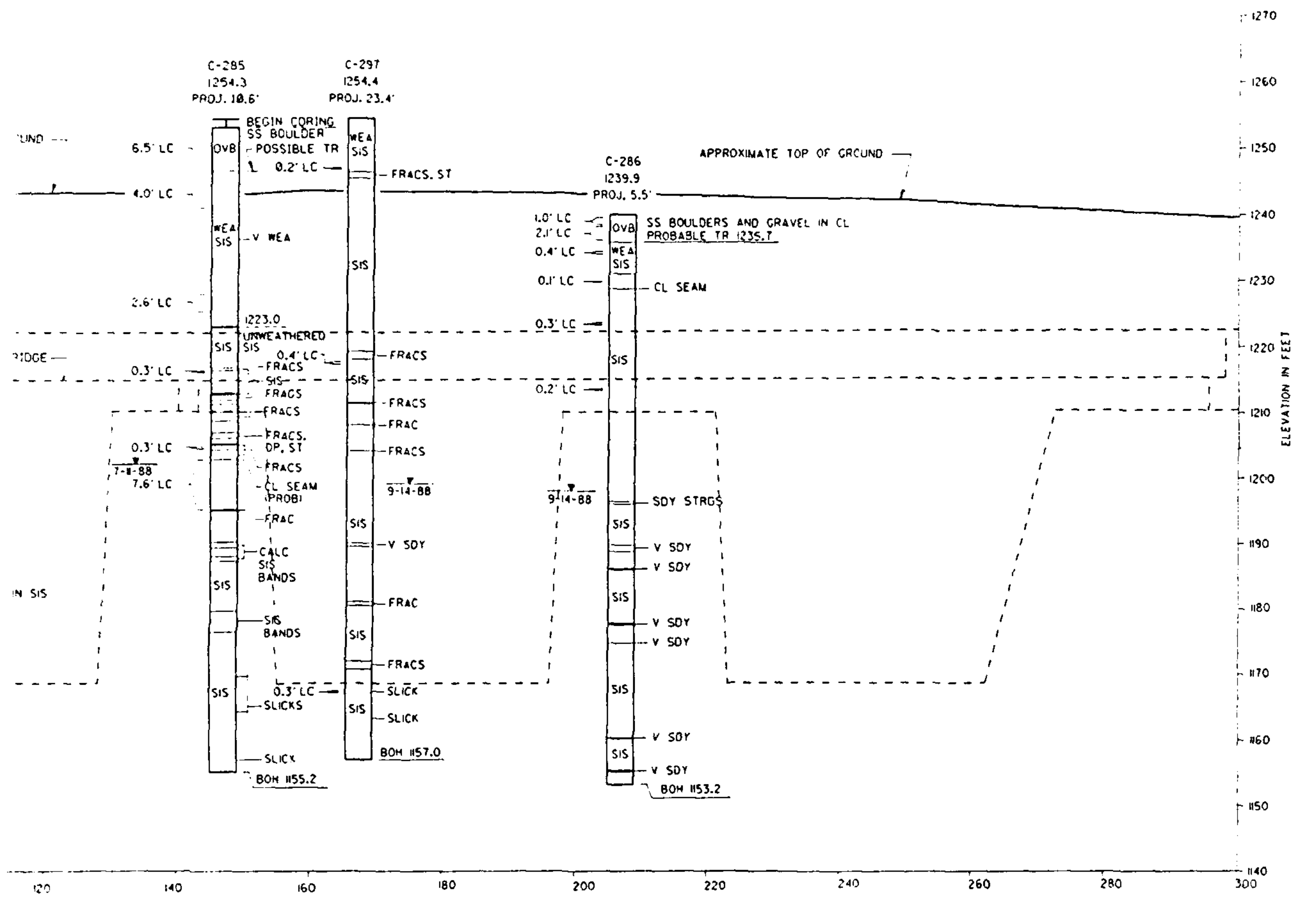
UPSTREAM PORTAL
GEOLOGIC SECTION
C-C

01A-64/33.2

PLATE C-3



5
4
D
C
B
A
ELEVATION IN FEET
C-257
1250.4
PROJ. 5.7'
DC-284
1245.7
PROJ. 3.5'
APPROXIMATE TOP OF GROUND
WASHBORED OVERBURDEN
PROB TR 1240.0
BEGIN CORING
HD, BR
SIS BANDS, HD, BR
SIS
BOULDERS AND CLAY
WASHBORED OVERBURDEN
BEGIN NO CORING
8.9' LC
2.6' LC
6-9-88
OVB
SS BOULDERS IN CLAY
TR 1220.5
FRAC, OP, DK BR ST
BRIDGE
ST WATERWAY
SLICK
1-21-88
0.6' LC
SIS BANDS, LNS & NODS, HD, BR
SIS BANDS, LNS & NODS, HD, BR
FRAC, PARTIALLY HLD
FRAC, OP, RUST ST
FRAC, TI, APPROX 40°
SIS BANDS
SIS BANDS, LNS & NODS, HD, BR
FRACS, HLD
FRAC, H/A, OP
SS BAND
SS
SS, SL CALC
SIS BANDS, LNS & NODES, HD, BR, IN SIS
SS BAND
SIS BAND
SIS BANDS
FRACS, H/A, TI
CALC
SIS
SIS BANDS
BOH 1156.9
BOH 1150.3
6.5' LC
4.0' LC
2.6' LC
0.3' LC
0.3' LC
7-4-88
7.6' LC
SH
SECTIO
SCALE:



SECTION D-D
SCALE: 1" = 10'

NOTE:
FOR NOTES, SEE DRAWING 01A-64/33.

1	5-31-89	CONFORMING TO REVIEW COMMENTS	E.P.O.	J.L.S.

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

UPSTREAM PORTAL
GEOLOGIC SECTION
D-D

01A-64/34.1

PLATE C-4

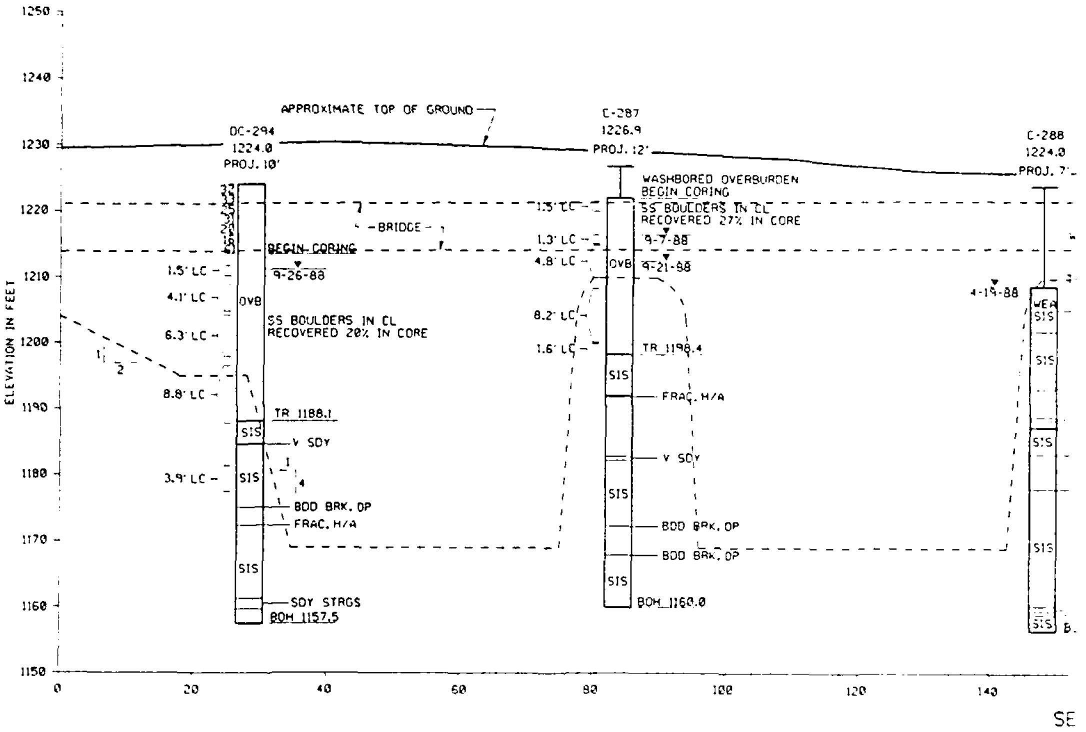
5 4

D

C

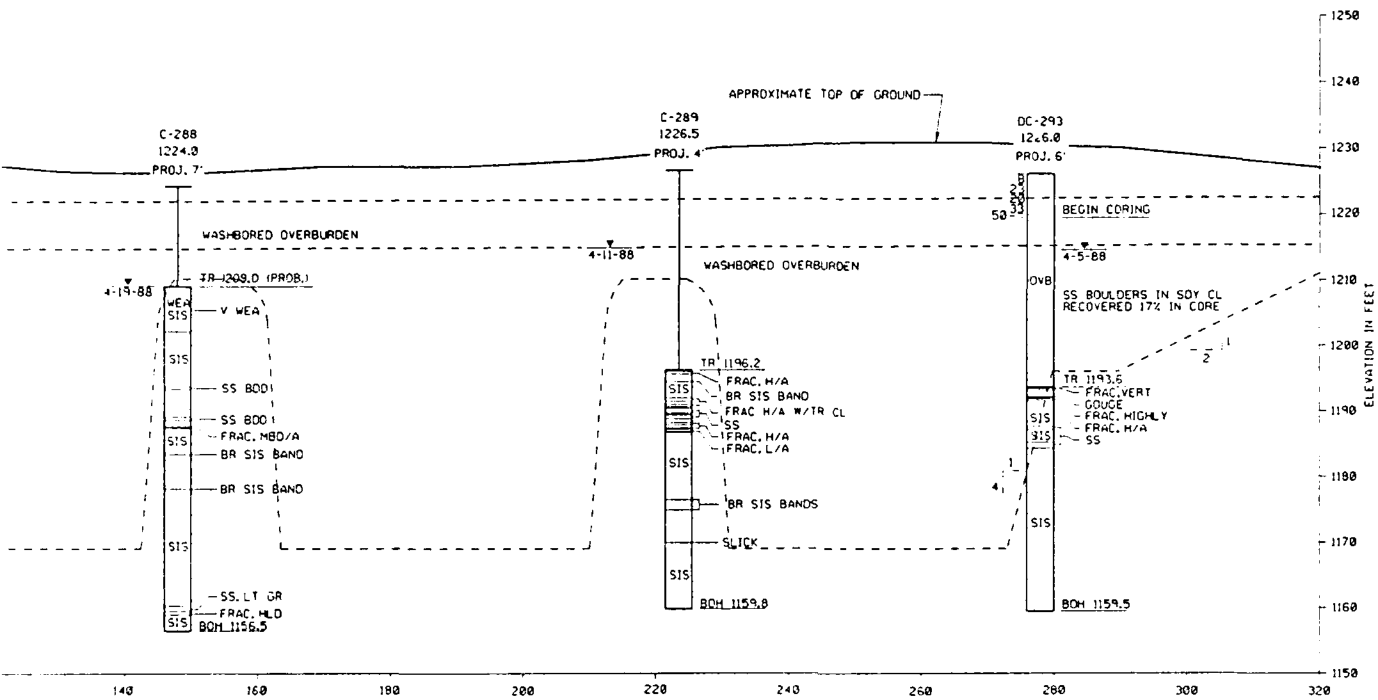
B

A



APPROXIMATE TOP OF GROUND
DC-294
1224.0
PROJ. 10'
C-287
1226.9
PROJ. 12'
C-288
1224.0
WASHBORED OVERBURDEN
BEGIN CORING
SS BOULDERS IN CL
RECOVERED 27% IN CORE
9-7-88
4-21-88
BRIDGE
BEGIN CORING
9-26-88
SS BOULDERS IN CL
RECOVERED 20% IN CORE
TR 1188.1
V SDY
BDD BRK. OP
FRAC. H/A
SDY STRGS
BOH 1157.5
TR 1198.4
FRAC. H/A
BDD BRK. OP
BOH 1160.0
4-19-88
ELEVATION IN FEET

5 4



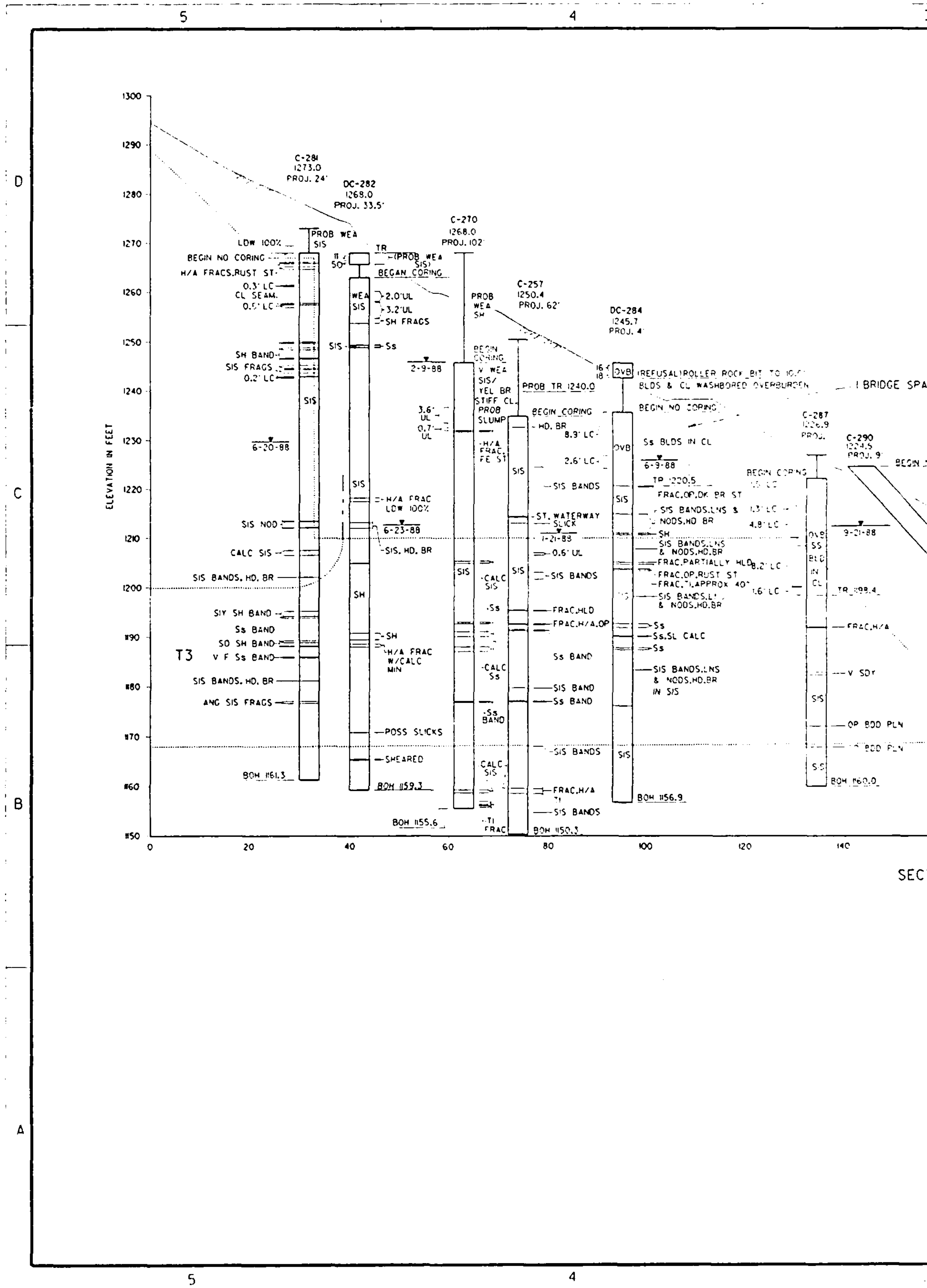
SECTION E-E
SCALE: 1" = 10'

NOTE:
FOR NOTES, SEE DRAWING 01A-64/33.

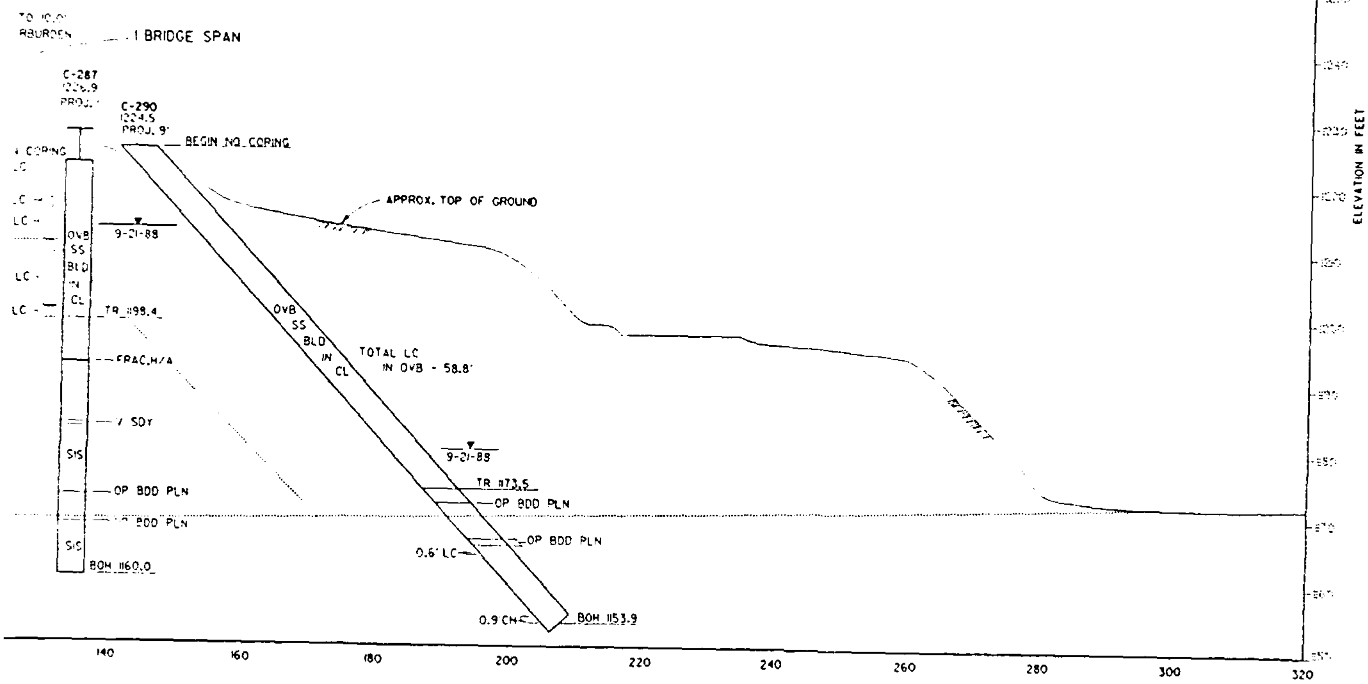
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

UPSTREAM PORTAL
GEOLOGIC SECTION
E-E

01A-64/35.1



5
4
3
D
C
B
A
T3
ELEVATION IN FEET
C-281
1273.0
PROJ. 24'
DC-282
1268.0
PROJ. 33.5'
C-270
1268.0
PROJ. 102'
C-257
1250.4
PROJ. 62'
DC-284
1245.7
PROJ. 4'
C-287
C-290
LOW 100%
BEGIN NO CORING
H/A FRACS,RUST ST
0.3' LC
CL SEAM
0.5' LC
SH BAND
SIS FRAGS
0.2' LC
6-20-88
SIS NOD
CALC SIS
SIS BANDS, HD. BR
SIY SH BAND
Ss BAND
SO SH BAND
V F Ss BAND
SIS BANDS, HD. BR
ANG SIS FRAGS
BOH 1161.3
PROB WEA SIS
TR
(PROB WEA SIS)
BEGAN CORING
2.0' UL
3.2' UL
SH FRAGS
Ss
H/A FRAC
LOW 100%
6-23-88
SIS, HD. BR
SH
H/A FRAC W/CALC MIN
POSS SLICKS
SHEARED
BOH 1159.3
2-9-88
PROB WEA SH
BEGIN CORING
V WEA SIS/ YEL BR STIFF CL
PROB SLUMP
H/A FRAC, FE ST
CALC SIS
Ss
CALC Ss
Ss BAND
CALC SIS
TI FRAC
BOH 1155.6
PROB TR 1240.0
BEGIN CORING
HD. BR
8.3' UL
2.6' LC
SIS BANDS
ST. WATERWAY SLICK
1-21-88
0.6' UL
SIS BANDS
FRAC,HLD
FRAC,H/A,OP
Ss BAND
SIS BAND
Ss BAND
SIS BANDS
FRAC,H/A
SIS BANDS
BOH 1150.3
OVB
(REFUSAL)ROLLER ROCK BIT TO
BLDS & CL WASHBORED OVERBURDEN
BRIDGE SPA
BEGIN NO CORING
Ss BLDS IN CL
6-9-88
TR 1220.5
FRAC,OP,DK BR ST
SIS BANDS,LNS & NODS,HD BR
SH
SIS BANDS,LNS & NODS,HD,BR
FRAC,PARTIALLY HLD
FRAC,OP,RUST ST
FRAC,TI,APPROX 40
SIS BANDS,L & NODS,HD,BR
Ss
Ss,SL CALC
Ss
SIS BANDS,LNS & NODS,HD,BR IN SIS
BOH 1156.9
BEGIN CORING
9-21-88
TR 1198.4
FRAC,H/A
V SDY
OP BDD PLN
BDD PLN
BOH 1160.0
SEC



SECTION F-F

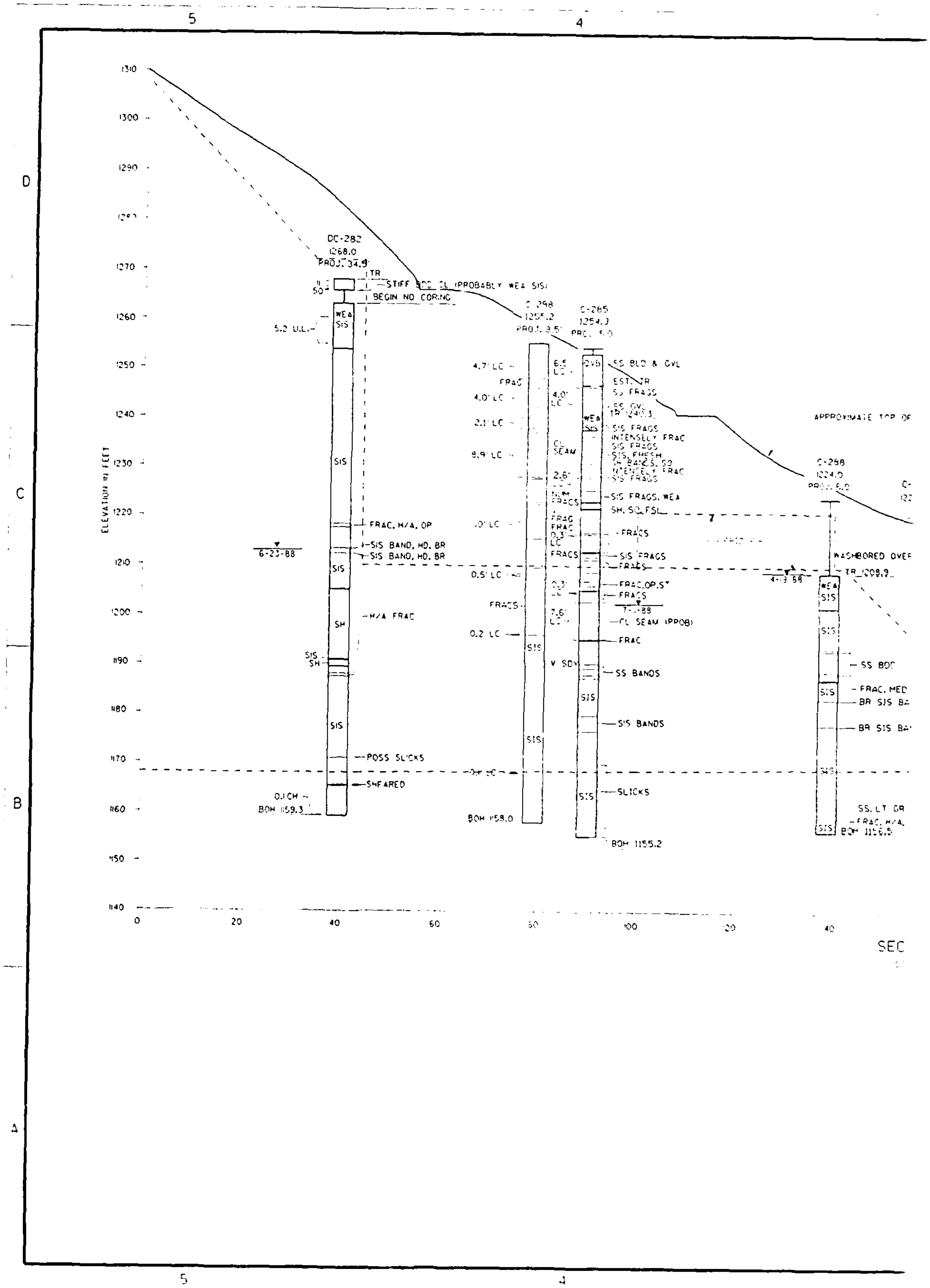
NOTE
1.FOR NOTES,SEE DRAWING OIA-64/33.

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

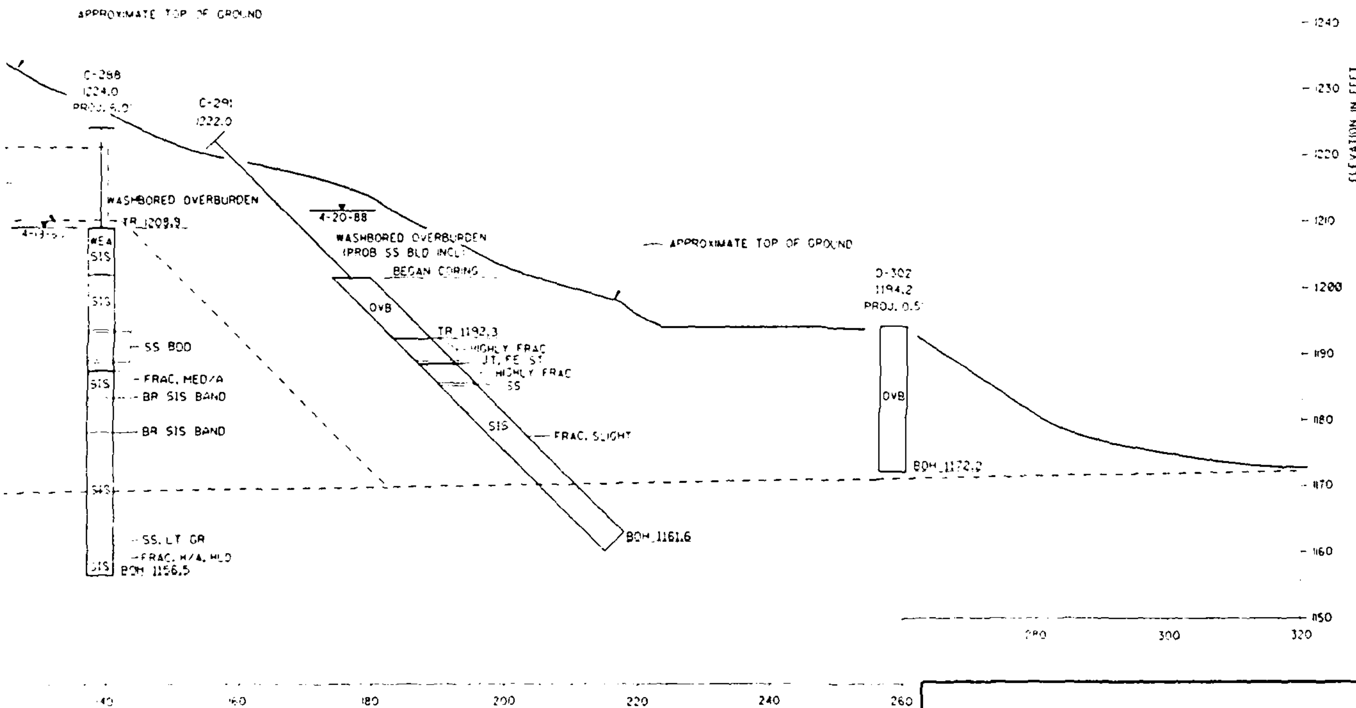
UPSTREAM PORTAL
GEOLOGIC SECTION
F-F

OIA-64/36.1

PLATE C-6



DC-282
1268.0
PROJ. 34.9'
TR
STIFF SDY CL (PROBABLY WEA SIS)
BEGIN NO CORING
WEA SIS
5.2 U.L.
SIS
FRAC, H/A, OP
SIS BAND, HD, BR
SIS BAND, HD, BR
6-23-88
SH
H/A FRAC
SIS SH
POSS SLICKS
SHEARED
0.1 CH
BOH 1159.3
C-298
1265.2
PROJ. 8.5'
C-285
1254.3
PROJ. 5.0
SS BLD & GVL
EST. TR
SS FRAGS
WEA SIS
SIS FRAGS
INTENSELY FRAC
SIS FRAGS
SH BANDS
SIS FRAGS, WEA
SH, SDY, FSL
FRACS
SIS FRAGS
FRAC, OP, ST
CL SEAM (PROB)
FRAC
SS BANDS
SIS BANDS
SLICKS
BOH 1155.2
BOH 1158.0
4.7' LC
4.0' LC
2.1' LC
8.9' LC
0.5' LC
0.2 LC
V SDY
APPROXIMATE TOP OF
C-288
1224.0
PROJ. 6.0'
WASHBORED OVER
TR 1208.9
4-13-88
WEA SIS
SS BDR
FRAC, MED
BR SIS BA
SS, LT GR
FRAC, H/A,
BOH 1156.5
ELEVATION IN FEET
1310
1300
1290
1270
1260
1250
1240
1230
1220
1210
1200
1190
1180
1170
1160
1150
1140
0
20
40
60
100
SEC
5
4
D
C
B
A



SECTION G-G

SCALE: 1" = 10'

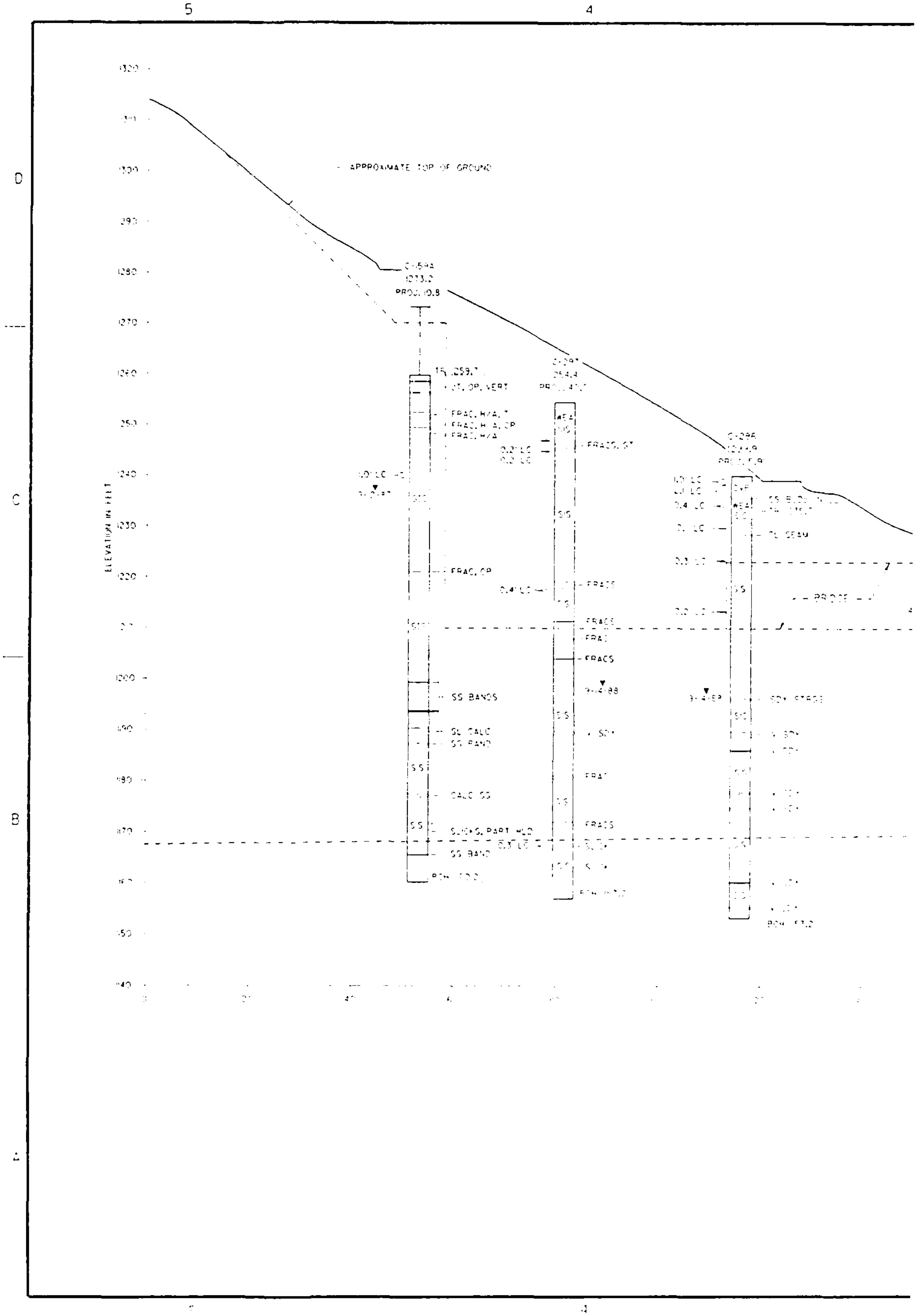
NOTE:

FOR NOTES, SEE DRAWING OIA-64/33.

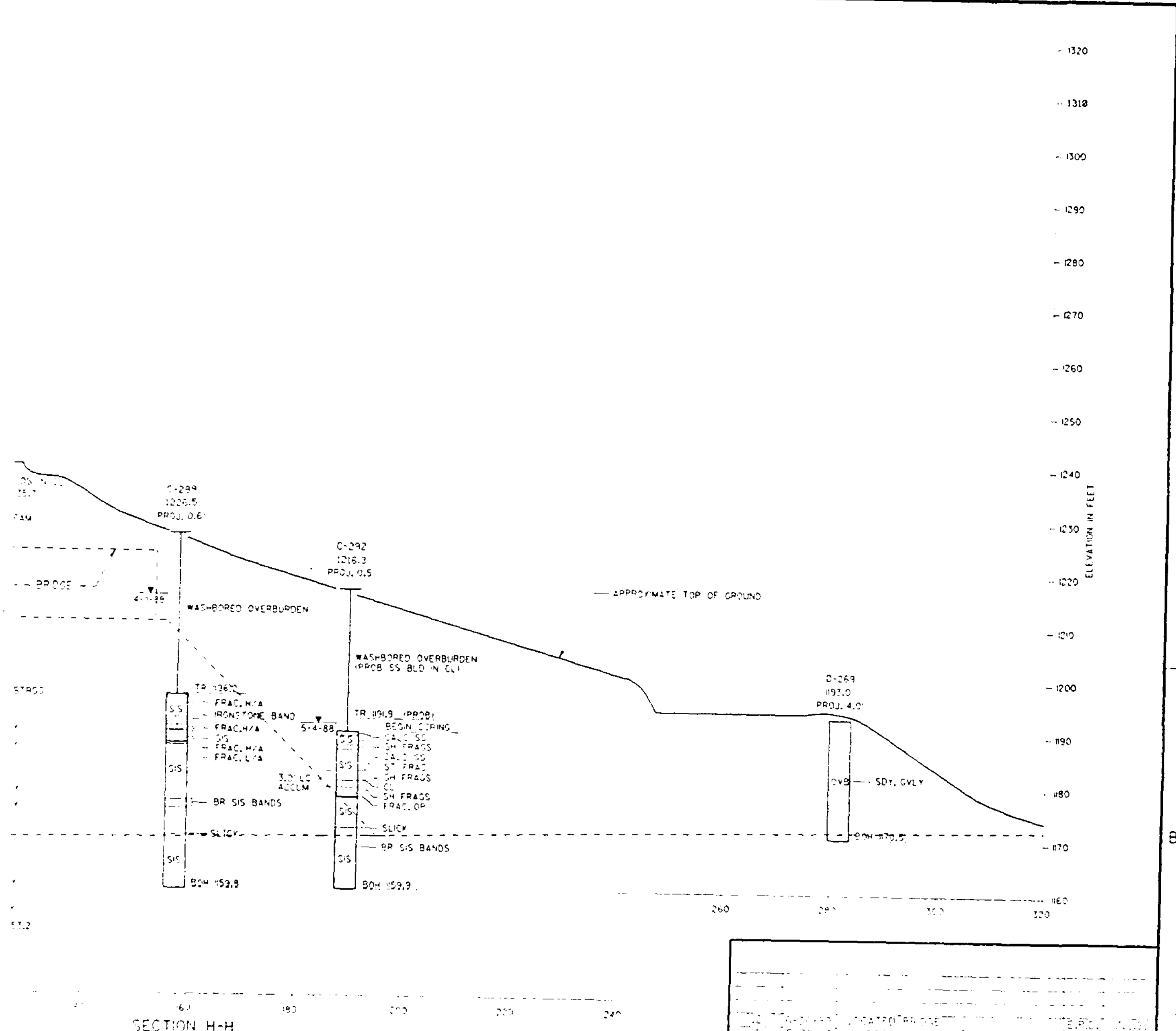
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

UPSTREAM PORTAL
GEOLOGIC SECTION
G-G

OIA-64/37.2



5
4
D
C
B
APPROXIMATE TOP OF GROUND
ELEVATION IN FEET
1320
1300
1280
1270
1260
1240
1230
1220
1200
C-594A
PROJ. 10.8
C-296
FRAC, OP
FRACS
SS BANDS
SS BAND
CALC SS
TL SEAM

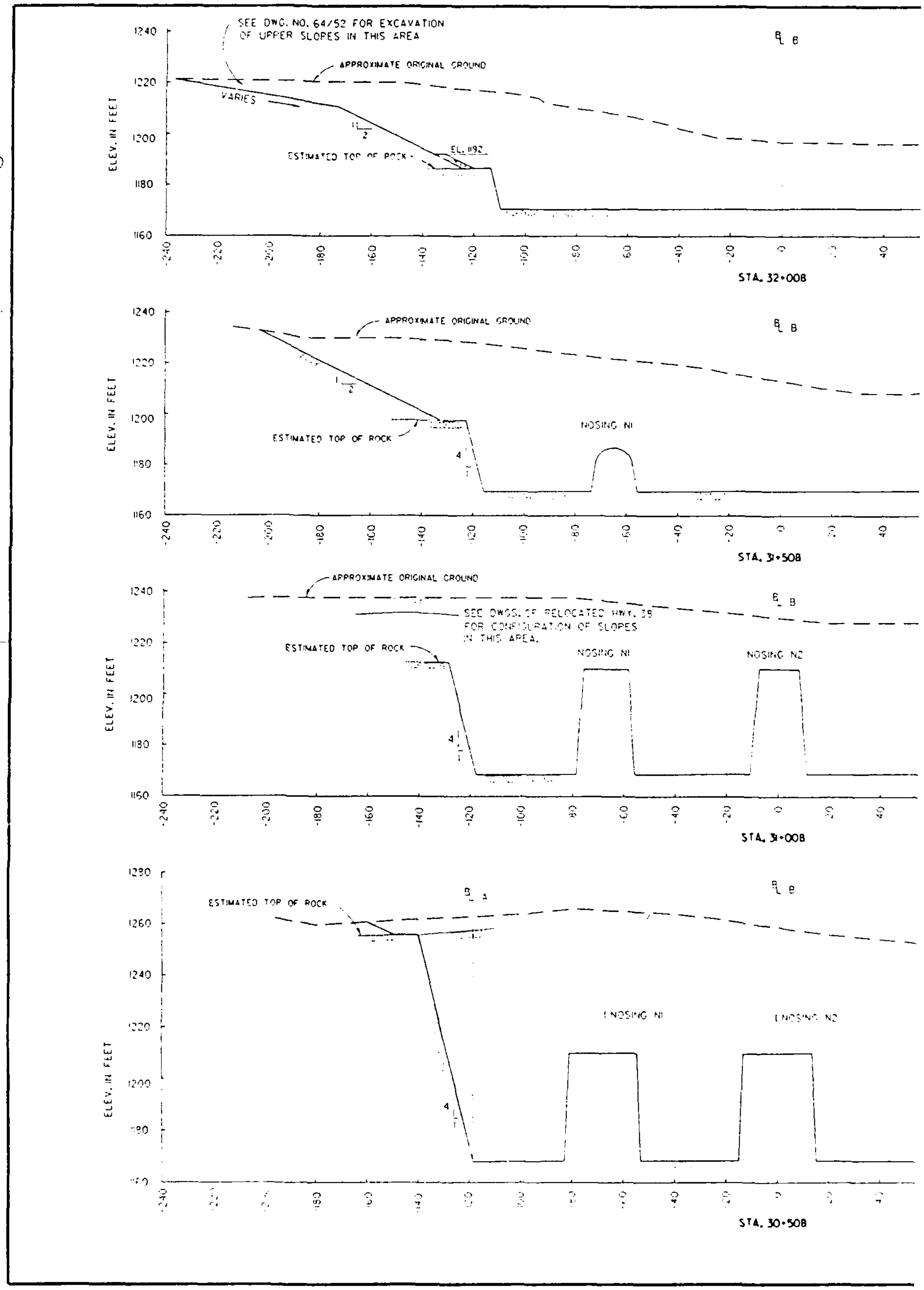


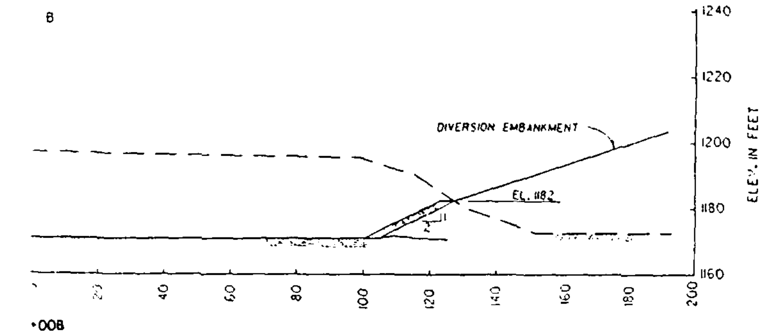
NOTE:
FOR NOTES, SEE DRAWING OIA-64/37.

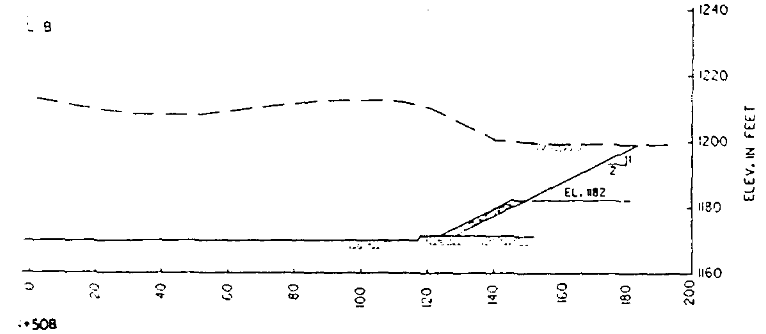
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

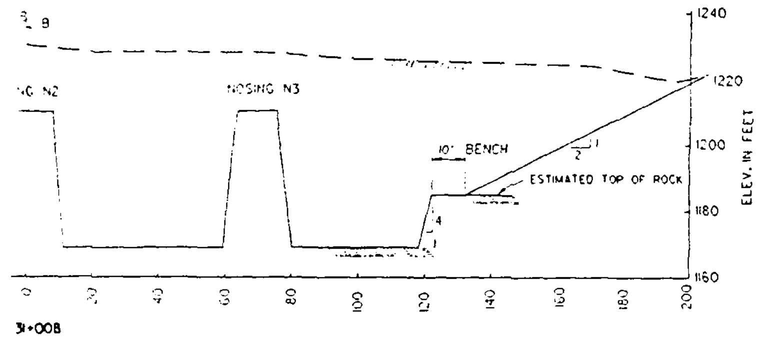
UPSTREAM PORTAL
GEOLOGIC SECTION

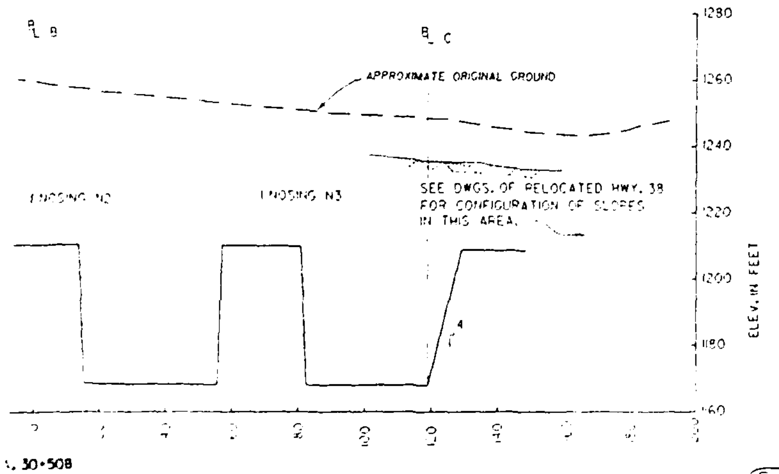
OIA-64/38.2


SEE DWG. NO. 64/52 FOR EXCAVATION OF UPPER SLOPES IN THIS AREA
APPROXIMATE ORIGINAL GROUND
VARIES
ESTIMATED TOP OF ROCK
EL. 1192
ELEV. IN FEET
STA. 32+00B
NOSING N1
STA. 31+50B
SEE DWGS. OF RELOCATED HWY. 38 FOR CONFIGURATION OF SLOPES IN THIS AREA.
NOSING N2
STA. 31+00B
STA. 30+50B









NOTES:

1. FOR PLAN OF UPSTREAM PORTAL, SEE DWG. NO. 64/51.
2. FOR DETAILS OF STONE PROTECTION, SEE DWG. NO. 64/56.
3. FOR DETAILS OF NOSES, SEE DWG. NO. 64/104.
4. FOR DIVERSION EMBANKMENT, SEE DWG. NO. 64/73.
5. ALL SLOPES, DIMENSIONS, AND ELEVATIONS ARE TYPICAL FOR THIS SHEET UNLESS OTHERWISE NOTED.
6. FOR CHANNEL INVERTS, SEE UPSTREAM PORTAL PLAN.

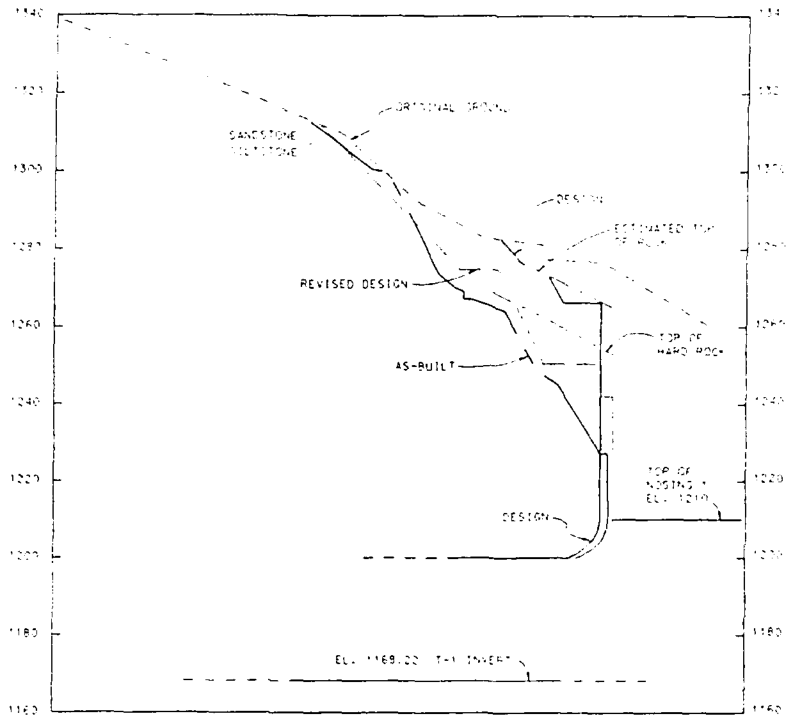
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE

DIVERSION TUNNELS

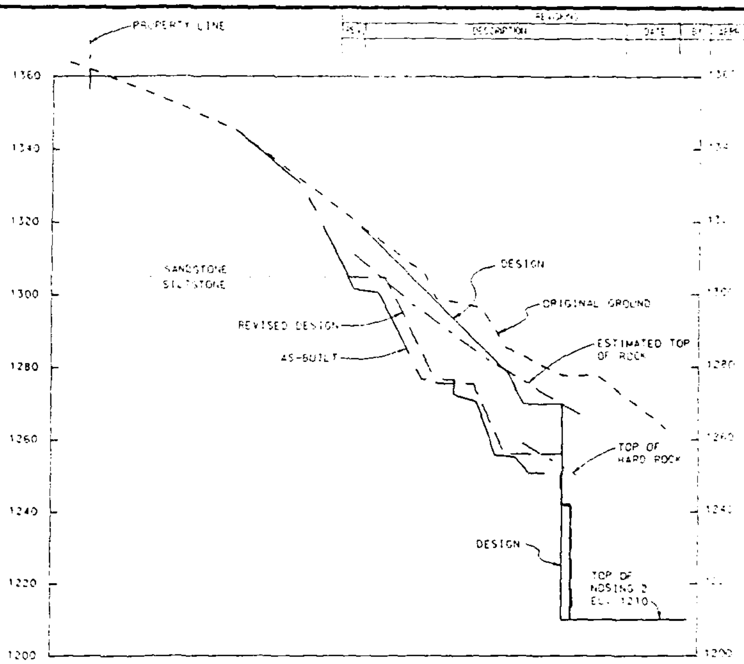
UPSTREAM PORTAL CROSS SECTIONS
STA. 30+50B THRU STA. 32+00B

OIA-64/54



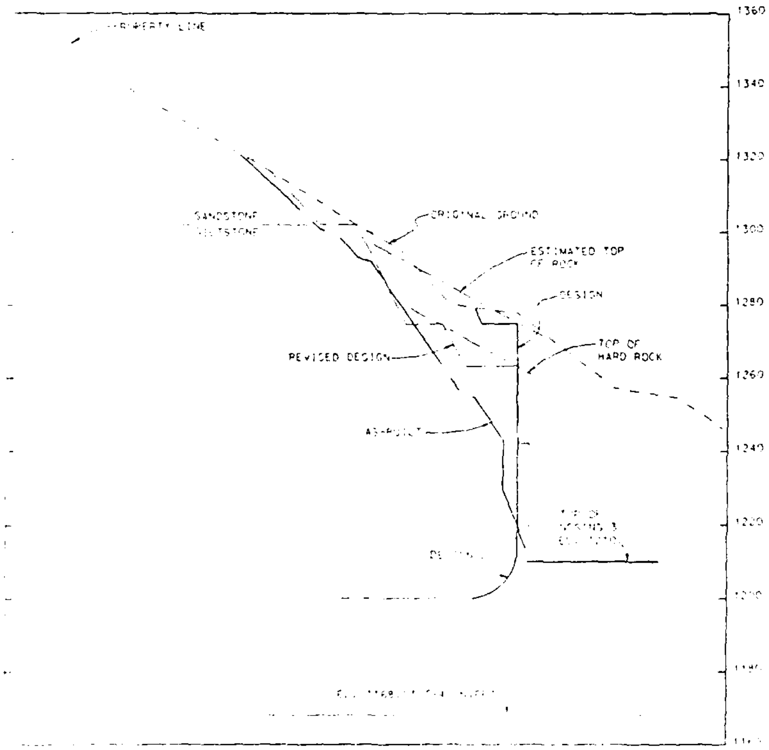
SECTION I
UPSTREAM PORTAL

CROSS-SECTION (100' LEFT
OF BASELINE B,DESIGN AND
AS-BUILT)



SECTION K
UPSTREAM PORTAL
CROSS-SECTION AT BASELINE B.
DESIGN AND AS-BUILT SLOPE

NOTE:
SEE PLATE C-19 FOR CROSS SECTION LOCATIONS.

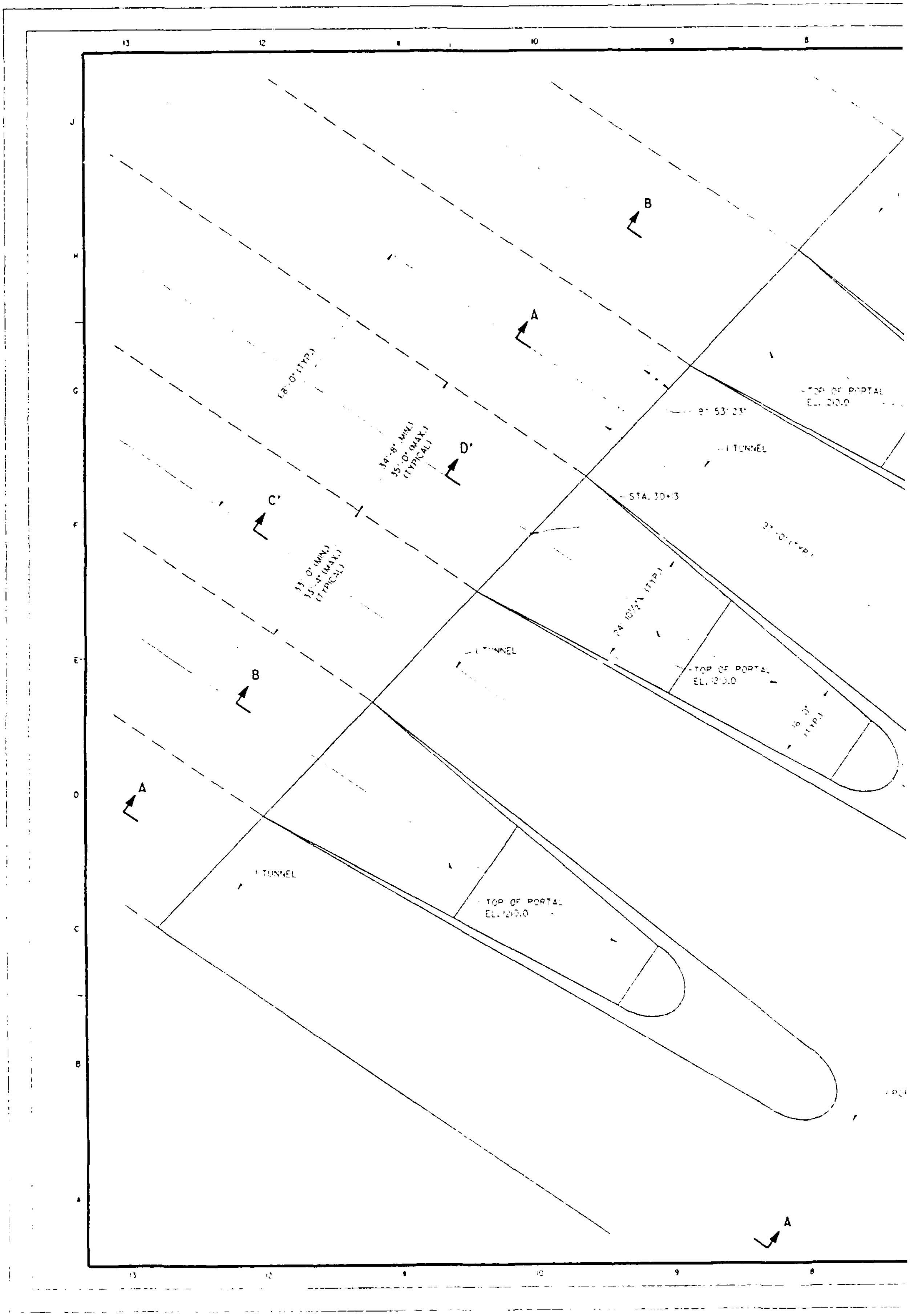


SECTION J
UPSTREAM PORTAL
CROSS-SECTION (100' RIGHT OF BASELINE B.DESIGN AND AS-BUILT)

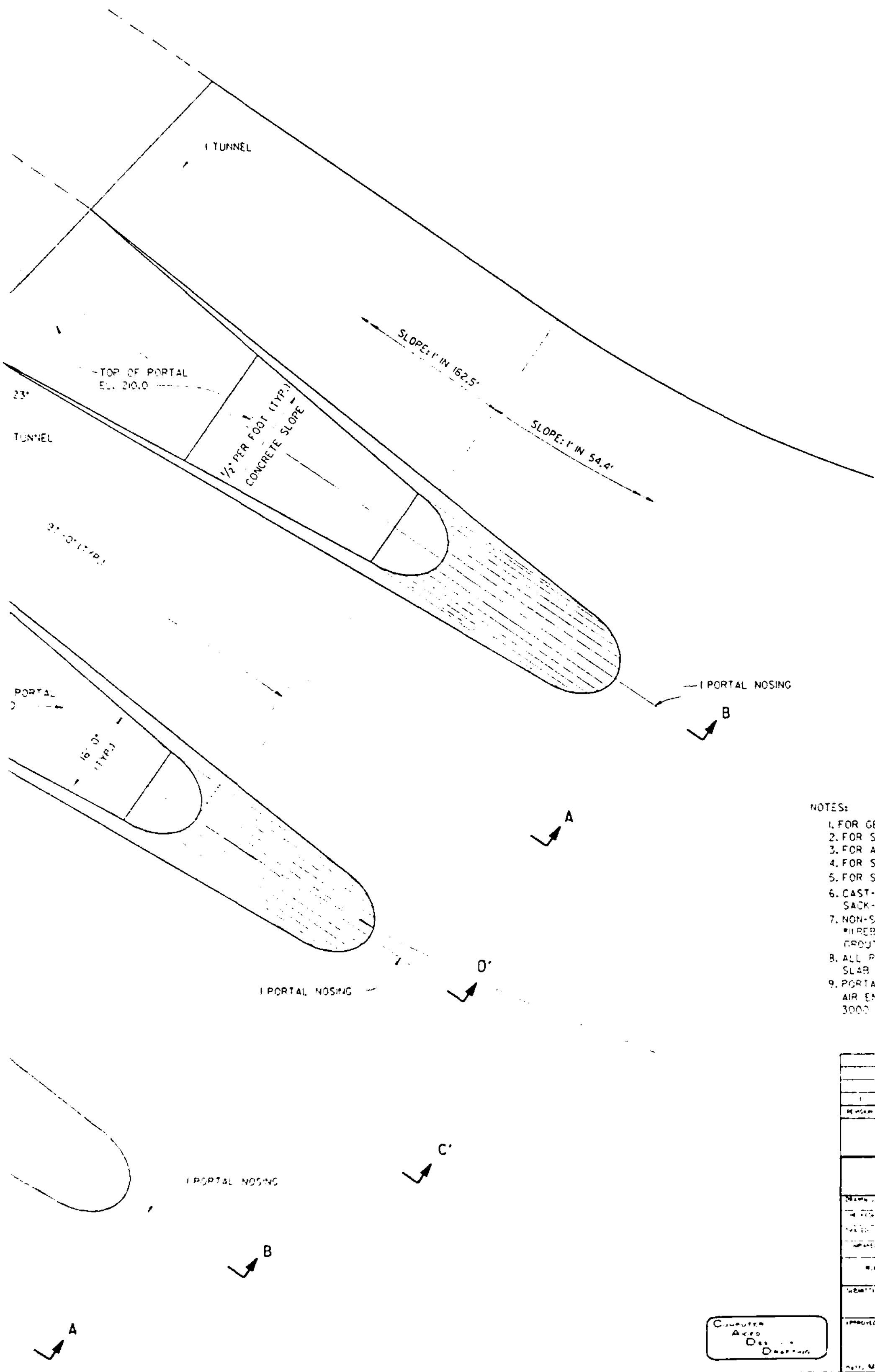
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS

KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION TUNNELS
UPSTREAM PORTAL BACKSLOPE
DESIGN & AS-BUILT CROSS SECTIONS

Q1A-4391



B
A
D'
C'
B
A
A
TOP OF PORTAL
EL. 1210.0
81° 53' 23"
TUNNEL
STA. 30+13
34'-8" (MIN.)
35'-0" (MAX.)
(TYPICAL)
33'-0" (MIN.)
33'-4" (MAX.)
(TYPICAL)
TUNNEL
TOP OF PORTAL
EL. 1210.0
TUNNEL
TOP OF PORTAL
EL. 1210.0



NOTES:

1. FOR GENERAL NOTES, SEE DWG. 64/2.
2. FOR STRUCTURAL NOTES, SEE DWG. 64/92.
3. FOR ADDITIONAL PORTAL AND TUNNEL GEOMETRY, SEE DWG. 64/51.
4. FOR SECTION A-A AND B-B, SEE DWG. 64/104.
5. FOR SECTION C'-C' AND D'-D', SEE DWG. 64/106.
6. CAST-IN-PLACE PORTAL NOSING CONCRETE SHALL HAVE A SACK-RUBBED FINISH.
7. NON-SHRINK GROUT SHALL BE USED FOR GROUTING THE #11 REBARS IN THE PORTAL NOSING INTO ROCK AND FOR GROUTING THE #6 REBARS IN THE TUNNEL SLAB INTO ROCK.
8. ALL REINFORCING IN THE PORTAL NOSINGS AND THE TUNNEL SLAB SHALL BE CONTINUOUS THRU CONSTRUCTION JOINTS.
9. PORTAL NOSING AND TUNNEL SLAB CONCRETE SHALL BE AIR ENTRAINMENT WITH A MIN. COMPRESSIVE STRENGTH OF 3000 PSI @ 28 DAYS.

REVISION	DATE	DESCRIPTION	BY	CHKD
1		GENERAL REVISIONS		M.R.

GRAPHIC SCALE

DEPARTMENT OF THE ARMY
NASHVILLE DISTRICT, CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY

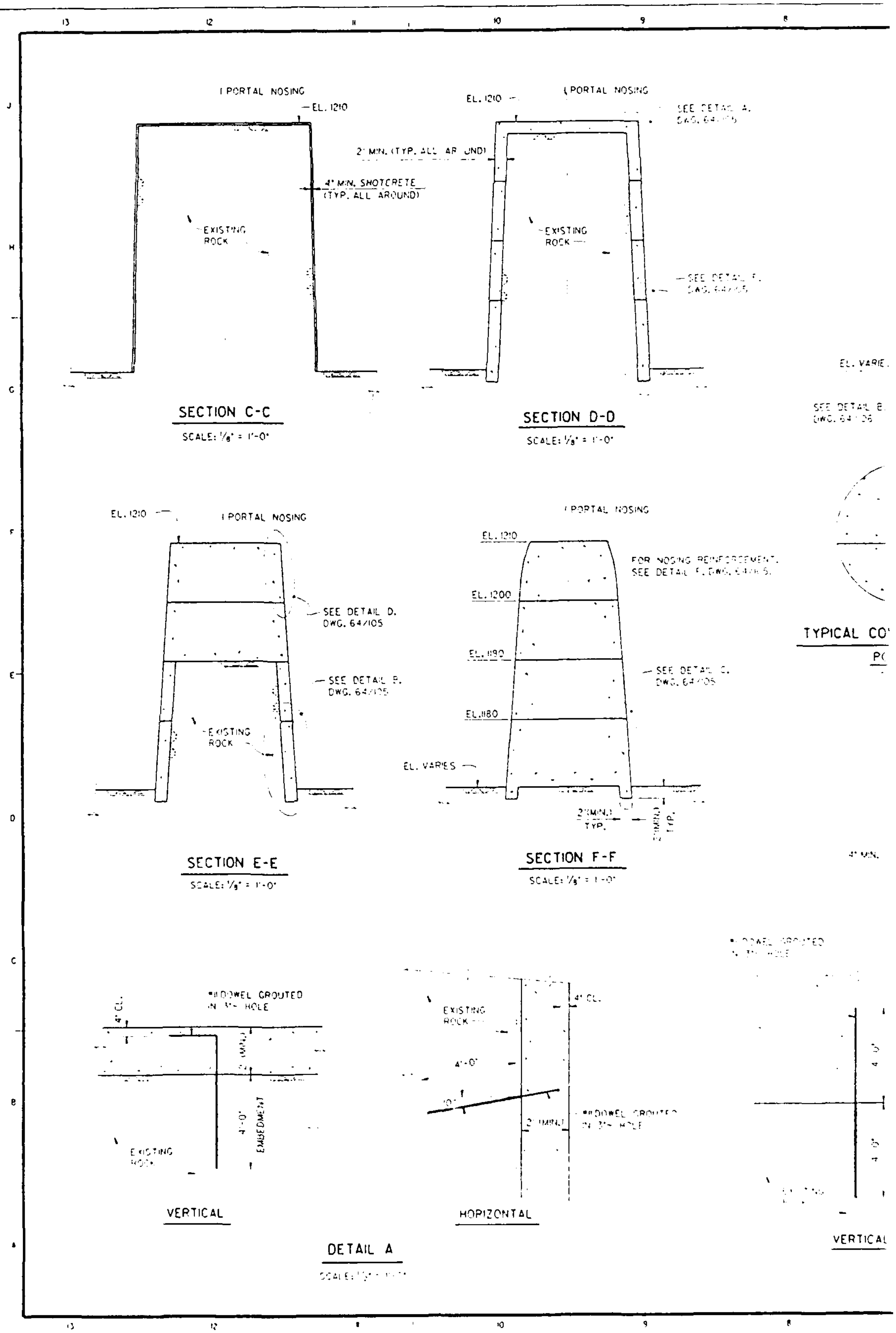
UPSTREAM PORTAL NOSINGS
PLAN

DATE: MARCH 1989

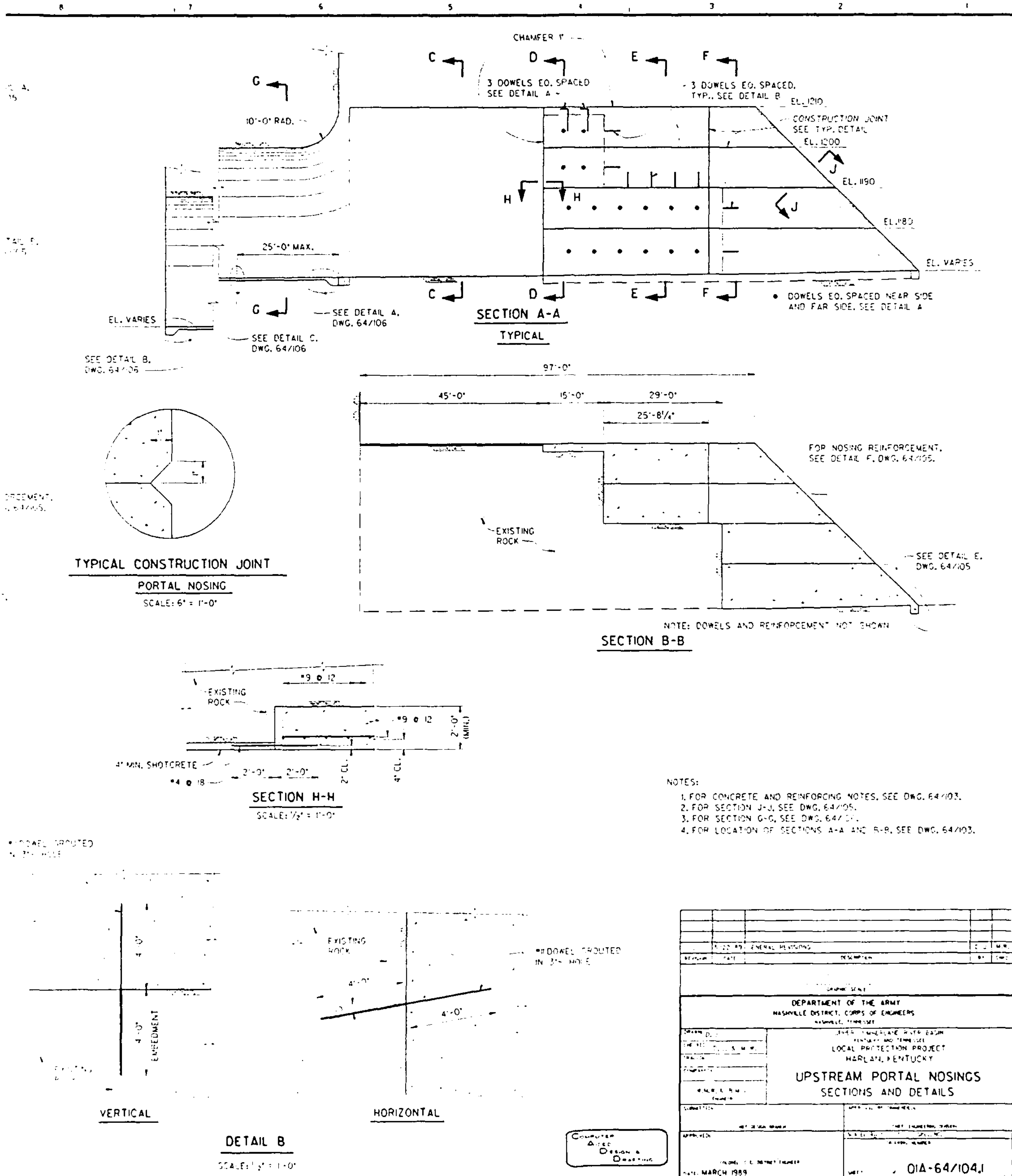
DRAWING NUMBER: 01A-64/103.1

RECORD DRAWING AS CONSTRUCTED

PLATE C-11



℄ PORTAL NOSING
EL. 1210
4" MIN. SHOTCRETE (TYP. ALL AROUND)
EXISTING ROCK
SECTION C-C
SCALE: 1/8" = 1'-0"
EL. 1210
℄ PORTAL NOSING
SEE DETAIL A, DWG. 64/105
2" MIN. (TYP. ALL AROUND)
EXISTING ROCK
SEE DETAIL F, DWG. 64/105
SECTION D-D
SCALE: 1/8" = 1'-0"
EL. 1210
℄ PORTAL NOSING
SEE DETAIL D, DWG. 64/105
SEE DETAIL B, DWG. 64/105
EXISTING ROCK
SECTION E-E
SCALE: 1/8" = 1'-0"
℄ PORTAL NOSING
EL. 1210
FOR NOSING REINFORCEMENT, SEE DETAIL F, DWG. 64/105
EL. 1200
EL. 1190
SEE DETAIL C, DWG. 64/105
EL. 1180
EL. VARIES
2" (MIN.) TYP.
SECTION F-F
SCALE: 1/8" = 1'-0"
EL. VARIES
SEE DETAIL E, DWG. 64/106
TYPICAL CO
#11 DOWEL GROUTED IN 3" HOLE
4" CL.
4'-0" EMBEDMENT
EXISTING ROCK
VERTICAL
4" CL.
EXISTING ROCK
4'-0"
10°
2" (MIN.)
#11 DOWEL GROUTED IN 3" HOLE
HORIZONTAL
DETAIL A
VERTICAL



NOTES:

1. FOR CONCRETE AND REINFORCING NOTES, SEE DWG. 64/103.
2. FOR SECTION J-J, SEE DWG. 64/105.
3. FOR SECTION G-G, SEE DWG. 64/1??.
4. FOR LOCATION OF SECTIONS A-A AND B-B, SEE DWG. 64/103.

DEPARTMENT OF THE ARMY
NASHVILLE DISTRICT, CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

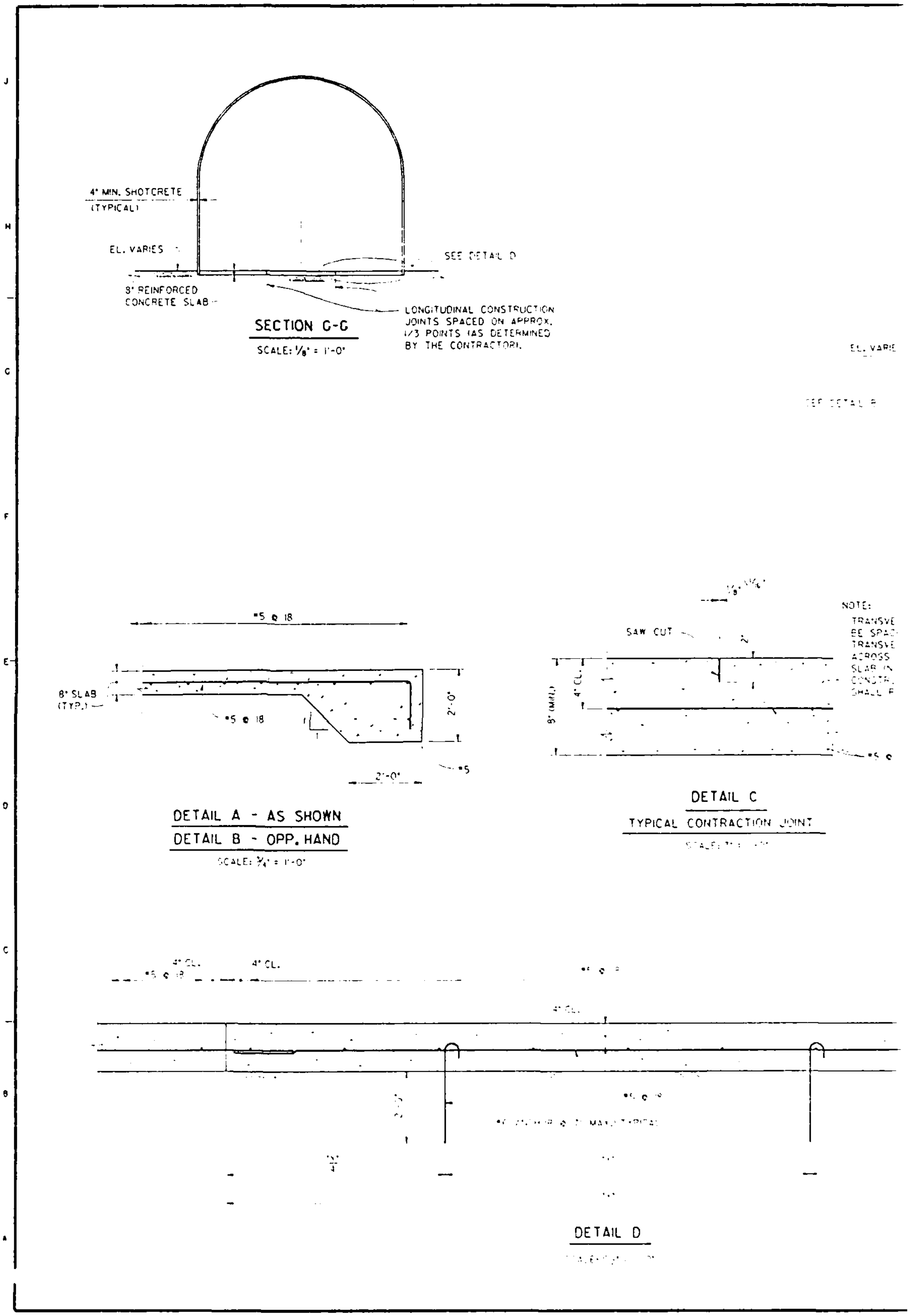
UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY

UPSTREAM PORTAL NOSINGS
SECTIONS AND DETAILS

DATE: MARCH 1989

01A-64/104.1

COMPUTER AIDED DESIGN & DRAFTING


4" MIN. SHOTCRETE
(TYPICAL)
EL. VARIES
SEE DETAIL D
8" REINFORCED
CONCRETE SLAB
LONGITUDINAL CONSTRUCTION
JOINTS SPACED ON APPROX.
1/3 POINTS (AS DETERMINED
BY THE CONTRACTOR).
SECTION G-G
SCALE: 1/8" = 1'-0"
EL. VARIE
#5 @ 18
8" SLAB
(TYP.)
#5 @ 18
2'-0"
2'-0"
#5
DETAIL A - AS SHOWN
DETAIL B - OPP. HAND
SCALE: 3/4" = 1'-0"
SAW CUT
4" CL.
8" (MIN.)
NOTE:
TRANSVE
BE SPAC
TRANSVE
ACROSS
SLAB IN
CONSTR
SHALL B
DETAIL C
TYPICAL CONTRACTION JOINT
4" CL.
4" CL.
#5 @ 18
4" CL.
DETAIL D

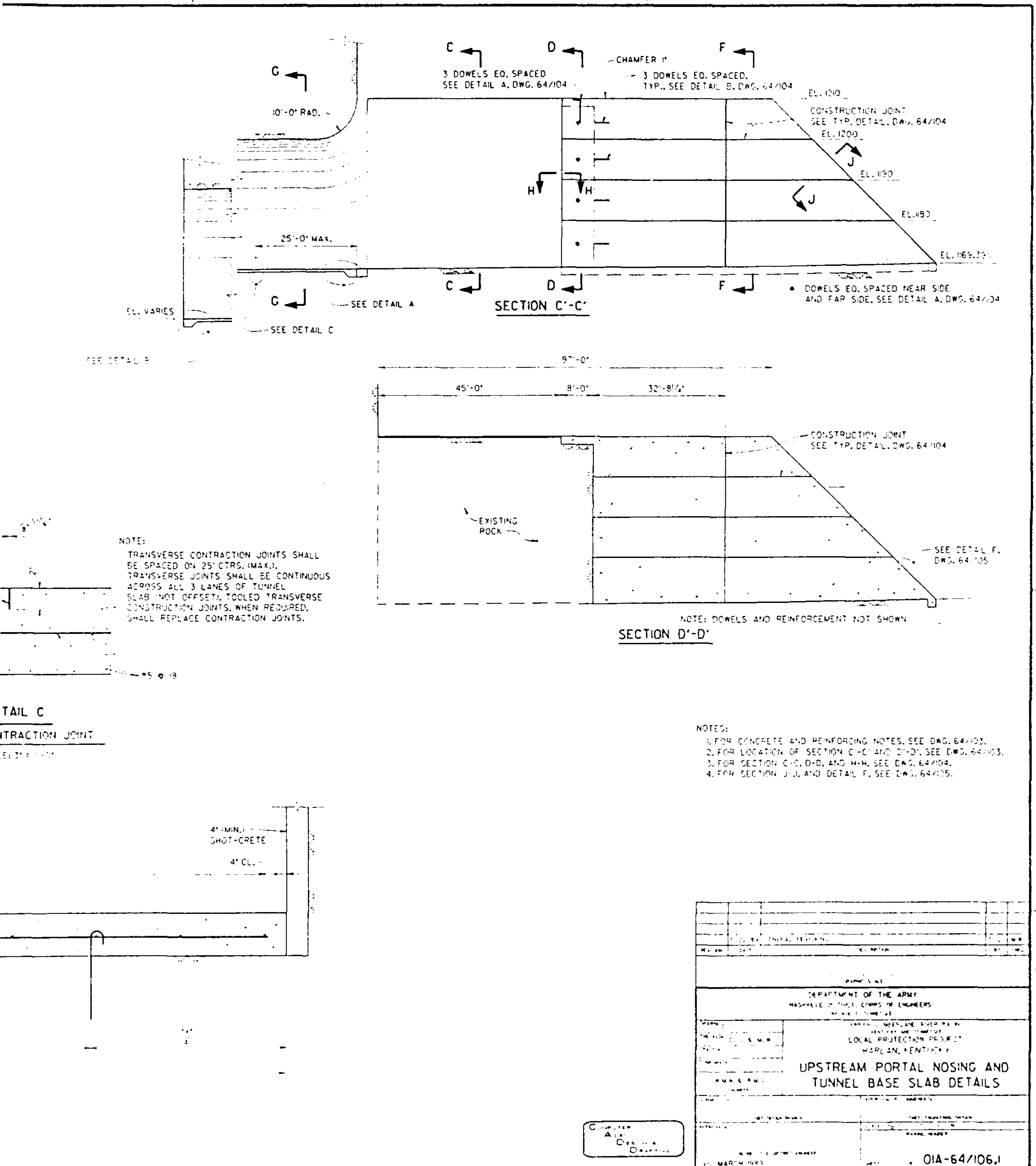
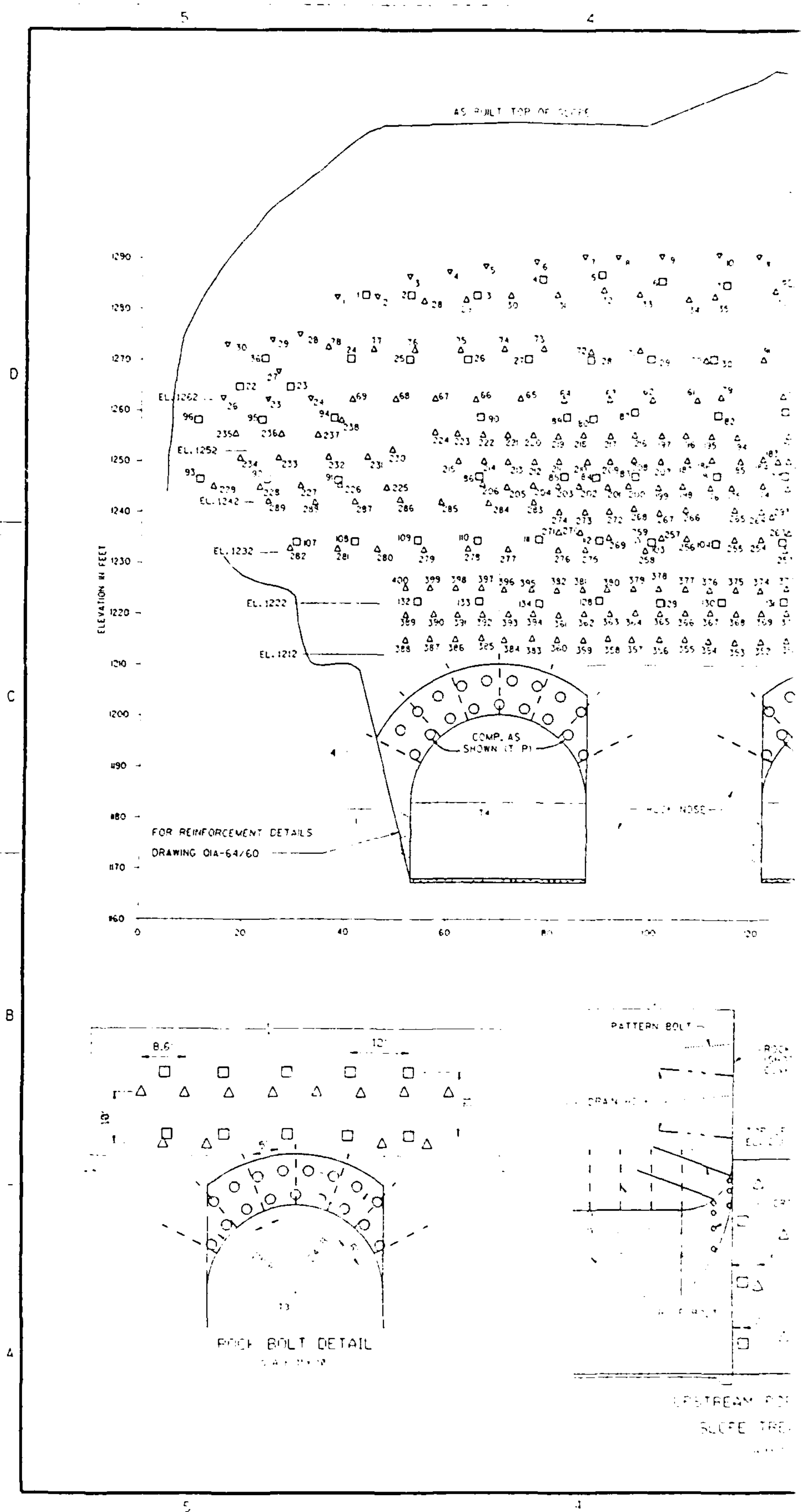
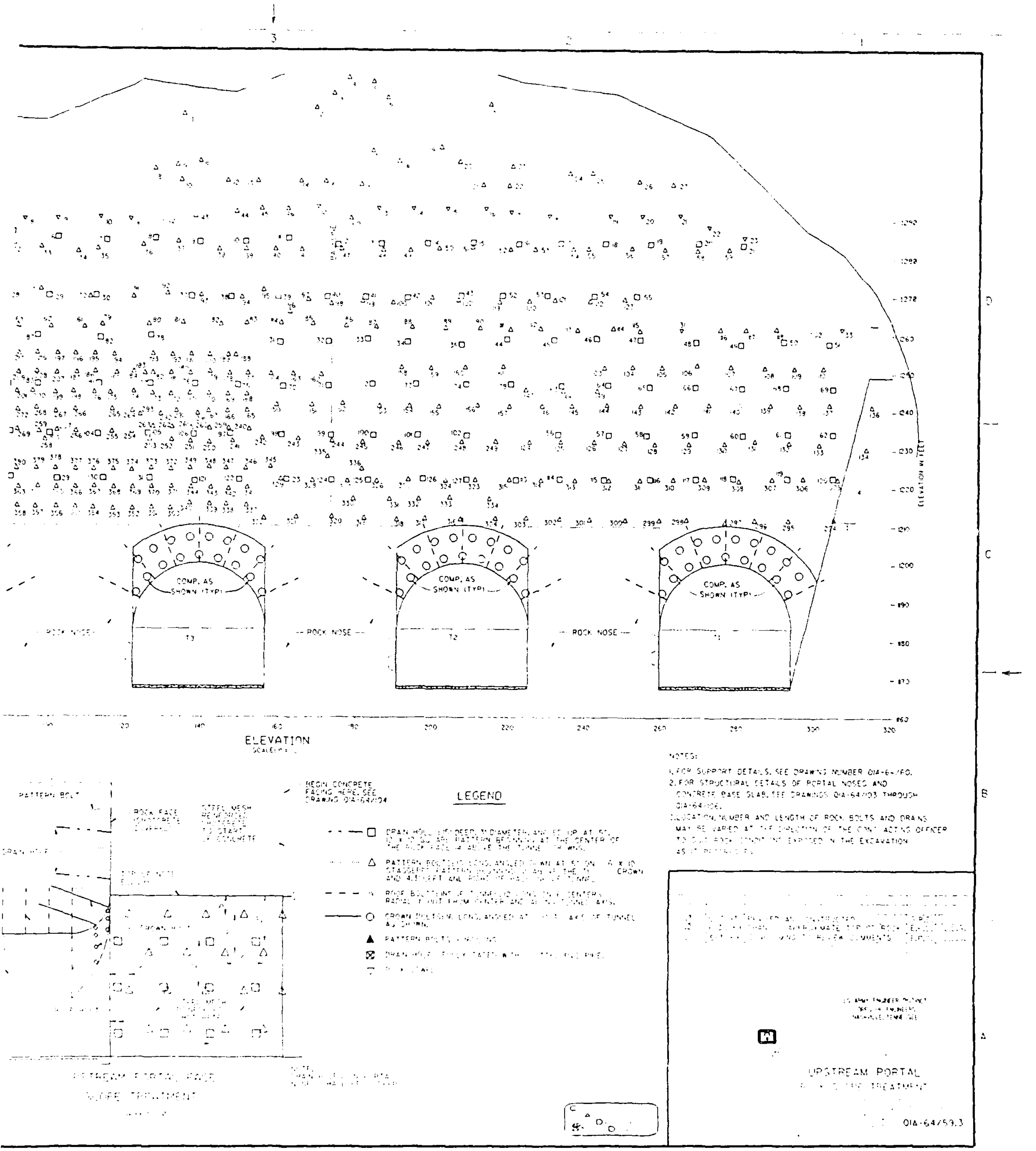

C
D
F
CHAMFER 1"
3 DOWELS EQ. SPACED
SEE DETAIL A, DWG. 64/104
3 DOWELS EQ. SPACED,
TYP., SEE DETAIL B, DWG. 64/104
EL. 1210
10'-0" RAD.
CONSTRUCTION JOINT
SEE TYP. DETAIL, DWG. 64/104
EL. 1200
EL. 1190
EL. 1180
EL. 1169.79
25'-0" MAX.
SEE DETAIL A
EL. VARIES
SEE DETAIL C
SECTION C'-C'
DOWELS EQ. SPACED NEAR SIDE
AND FAR SIDE, SEE DETAIL A, DWG. 64/104
97'-0"
45'-0"
8'-0"
32'-8¼"
CONSTRUCTION JOINT
SEE TYP. DETAIL, DWG. 64/104
EXISTING
ROCK
SEE DETAIL F,
DWG. 64/105
NOTE: DOWELS AND REINFORCEMENT NOT SHOWN
SECTION D'-D'
NOTE:
TRANSVERSE CONTRACTION JOINTS SHALL
BE SPACED ON 25' CTRS. (MAX.).
TRANSVERSE JOINTS SHALL BE CONTINUOUS
ACROSS ALL 3 LANES OF TUNNEL
SLAB (NOT OFFSET). TOOLED TRANSVERSE
CONSTRUCTION JOINTS, WHEN REQUIRED,
SHALL REPLACE CONTRACTION JOINTS.
#5 @ 18
TAIL C
NTRACTION JOINT
NOTES:
1. FOR CONCRETE AND REINFORCING NOTES, SEE DWG. 64/103.
2. FOR LOCATION OF SECTION C'-C' AND D'-D', SEE DWG. 64/103.
3. FOR SECTION C-C, D-D, AND H-H, SEE DWG. 64/104.
4. FOR SECTION J-J, AND DETAIL F, SEE DWG. 64/105.
4" (MIN.)
SHOT-CRETE
4" CL.
DEPARTMENT OF THE ARMY
NASHVILLE DISTRICT, CORPS OF ENGINEERS
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
UPSTREAM PORTAL NOSING AND
TUNNEL BASE SLAB DETAILS
MARCH 1983
01A-64/106.1

PLATE C-13

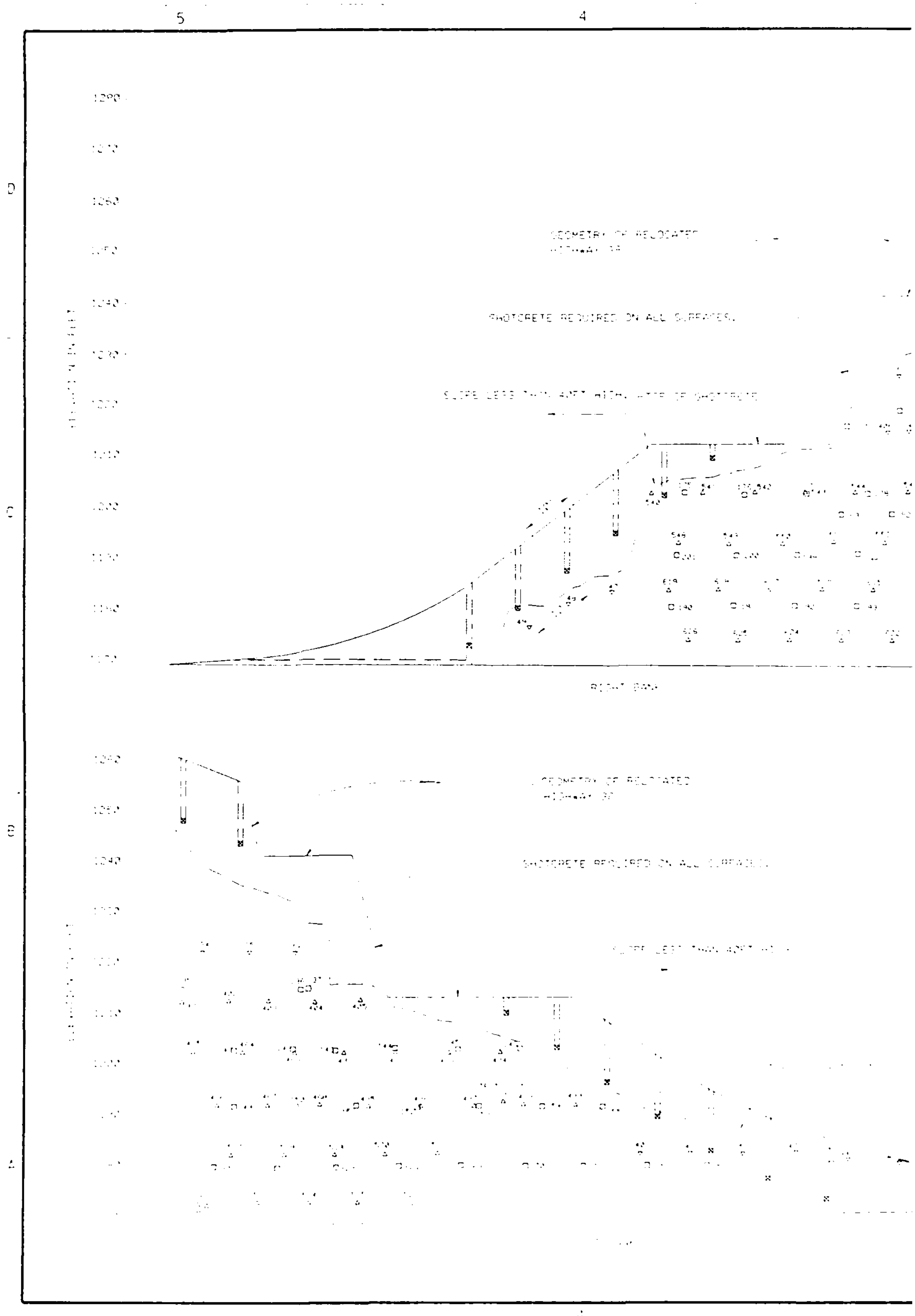


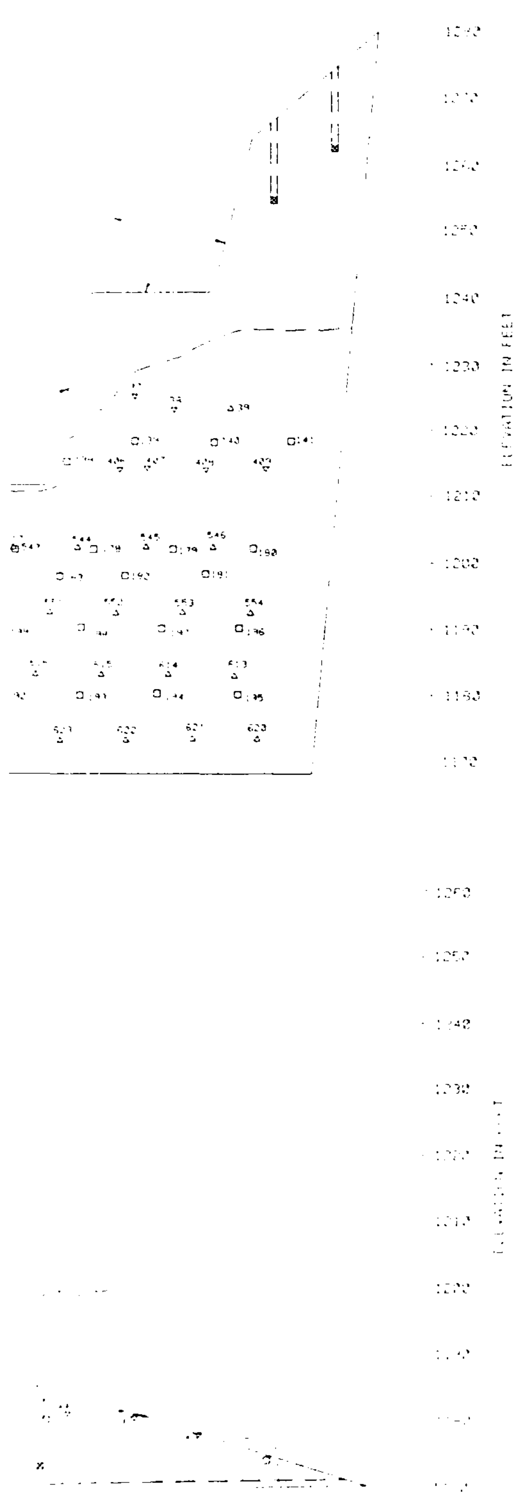
AS BUILT TOP OF SLOPE
ELEVATION IN FEET
EL. 1262
EL. 1252
EL. 1242
EL. 1232
EL. 1222
EL. 1212
COMP. AS SHOWN (T. P)
FOR REINFORCEMENT DETAILS
DRAWING OIA-64/60
ROCK BOLT DETAIL
PATTERN BOLT



ELEVATION
COMP. AS SHOWN (TYP)
ROCK NOSE
T3
T2
T1
BEGIN CONCRETE FACING HERE. SEE DRAWING OIA-64/104
LEGEND
NOTES:
1. FOR SUPPORT DETAILS, SEE DRAWING NUMBER OIA-64/FO.
2. FOR STRUCTURAL DETAILS OF PORTAL NOSES AND CONCRETE BASE SLAB, SEE DRAWINGS OIA-64/103 THROUGH OIA-64/106.
PATTERN BOLT
DRAIN HOLE
UPSTREAM PORTAL
OIA-64/59.3

PLATE C-14


5
4
D
C
B
A
GEOMETRY OF RELOCATED
SHOTCRETE REQUIRED ON ALL SURFACES.
RIGHT BANK
GEOMETRY OF RELOCATED
SHOTCRETE REQUIRED ON ALL SURFACES.



LEGEND

□ DRAIN HOLES, 15' DEEP, 3" DIAMETER, ANGLED UP AT 5 DEGREES IN A 10' X 10' SQUARE PATTERN.

△ PATTERN BOLTS, 10' LONG, ANGLED DOWN AT 5 DEGREES ON 10' X 10' STAGGERED PATTERN.

⊠ DRAIN HOLES FULLY CASED WITH SLOTTED PVC PIPE.

▽ ROCK DOWELS.

= STRIPDRAINS.

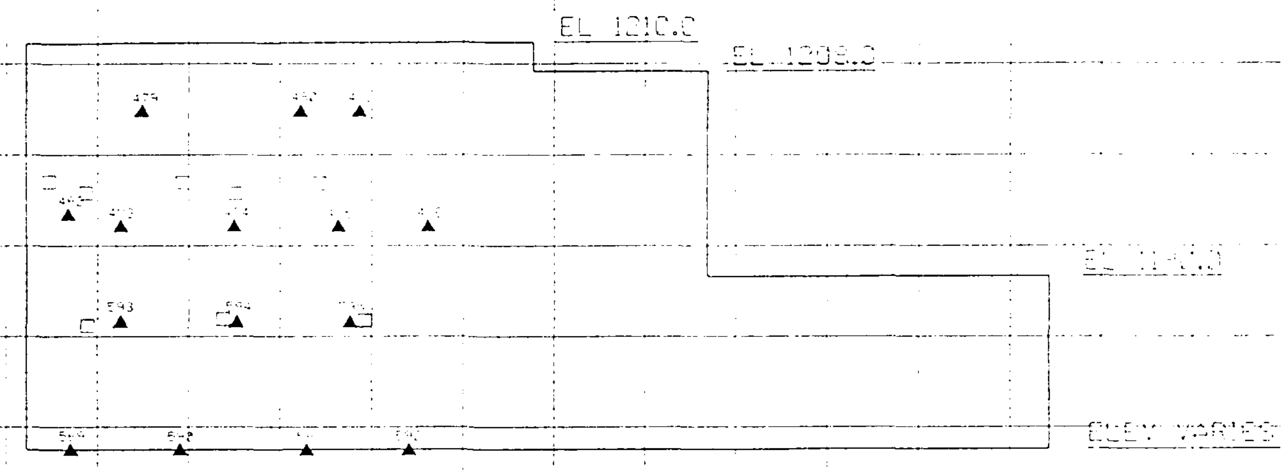
NOTE

1. THE LOCATIONS FOR ROCK BOLTS, DOWELS, AND DRAIN HOLES ON THIS DRAWING ARE APPROXIMATE AND MAY BE ADJUSTED IN THE FIELD.
2. FOR DETAILS OF SLOPE TREATMENT SEE DRAWING DIA-64/62.
3. TOP OF SLOPE SHOWN IS AT ESTIMATED BENCH ELEVATION.

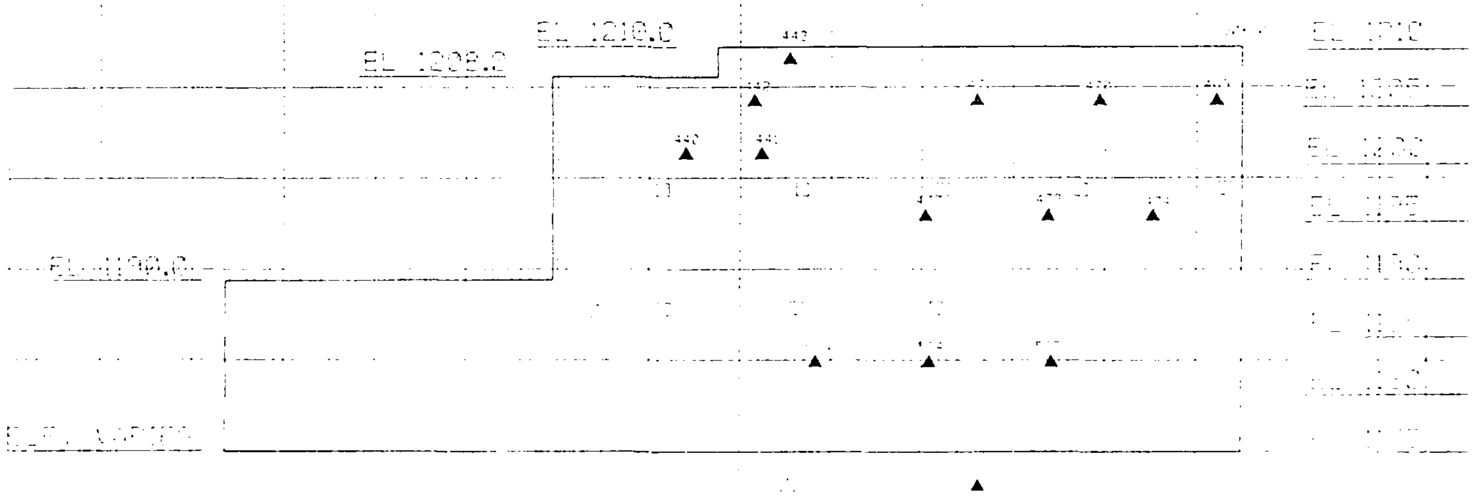
[illegible]STREAM PORTAL
[illegible] SLOPE ROCK TREATMENT

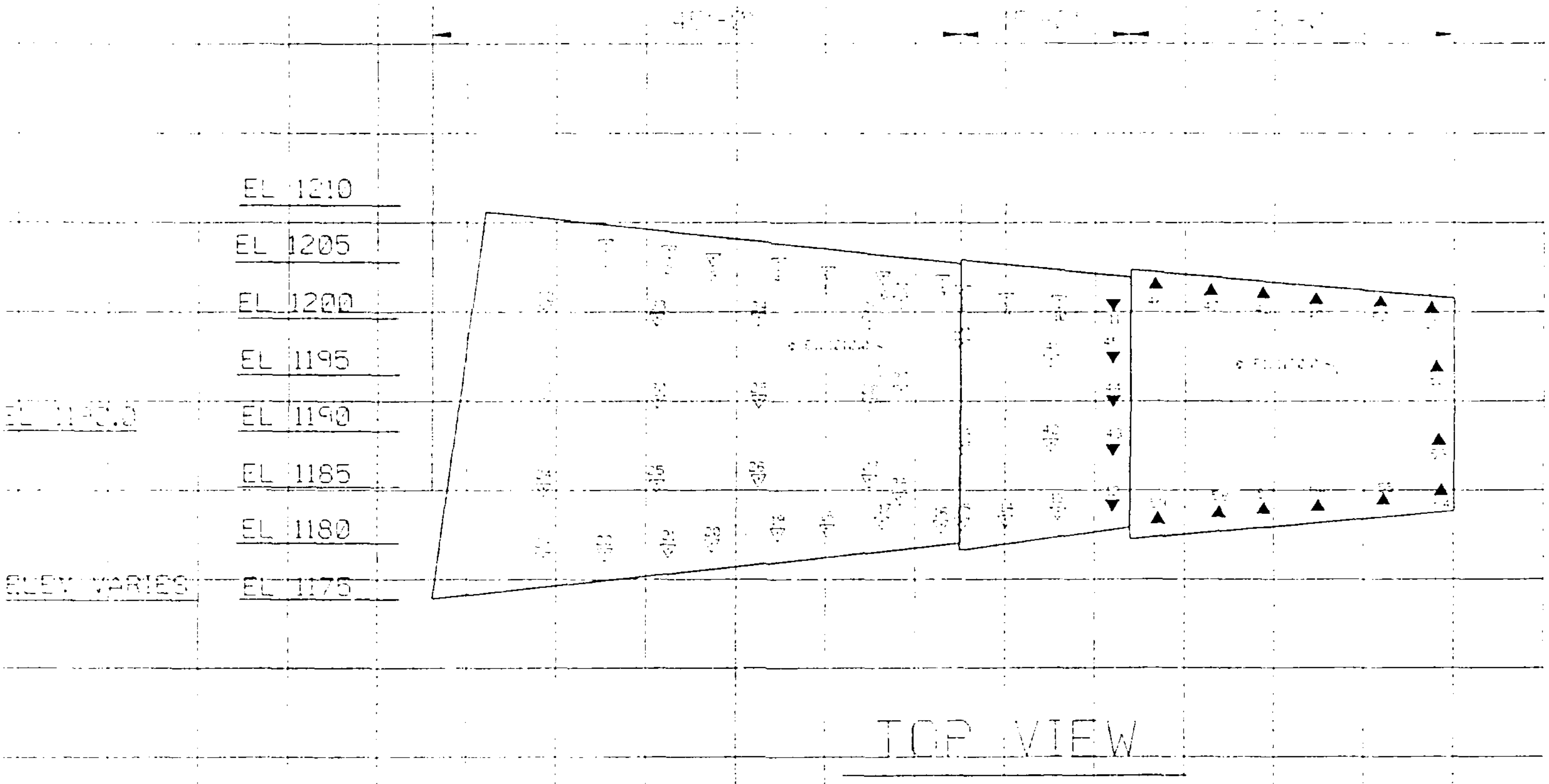
DIA-64/[illegible]

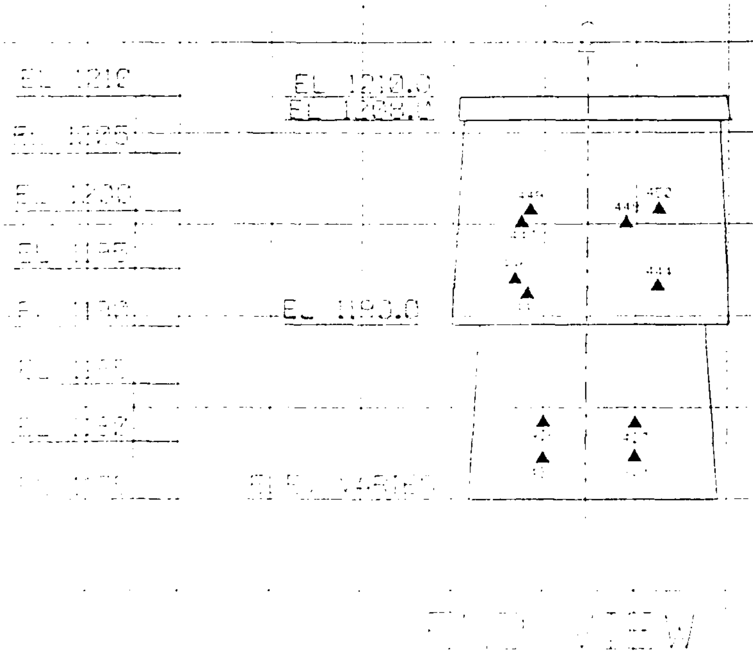
PLATE C-15



RIGHT SIDE VIEW



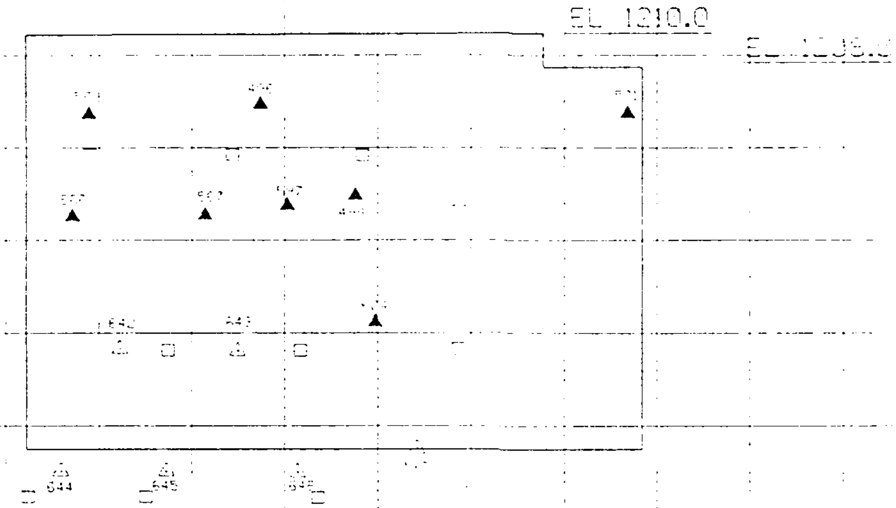




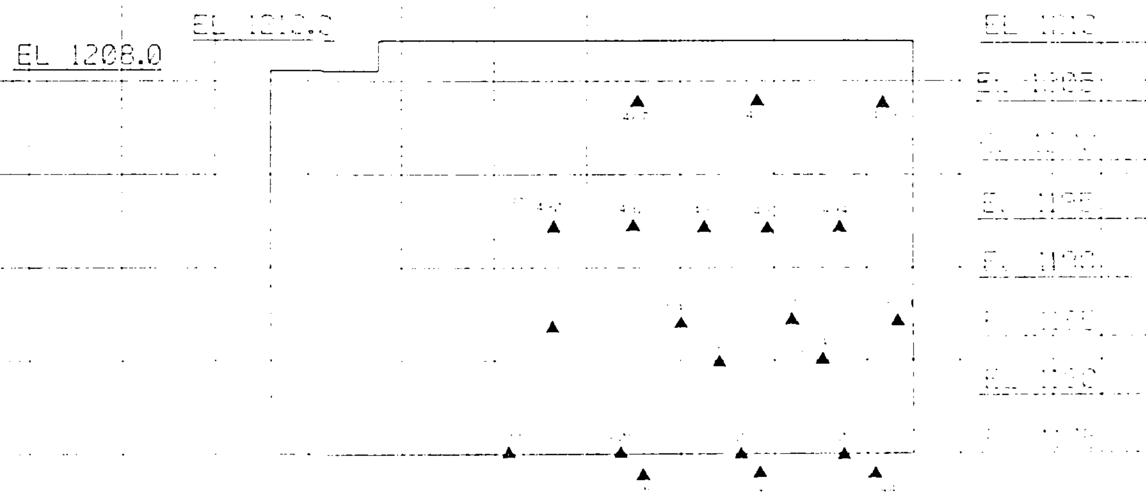
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS

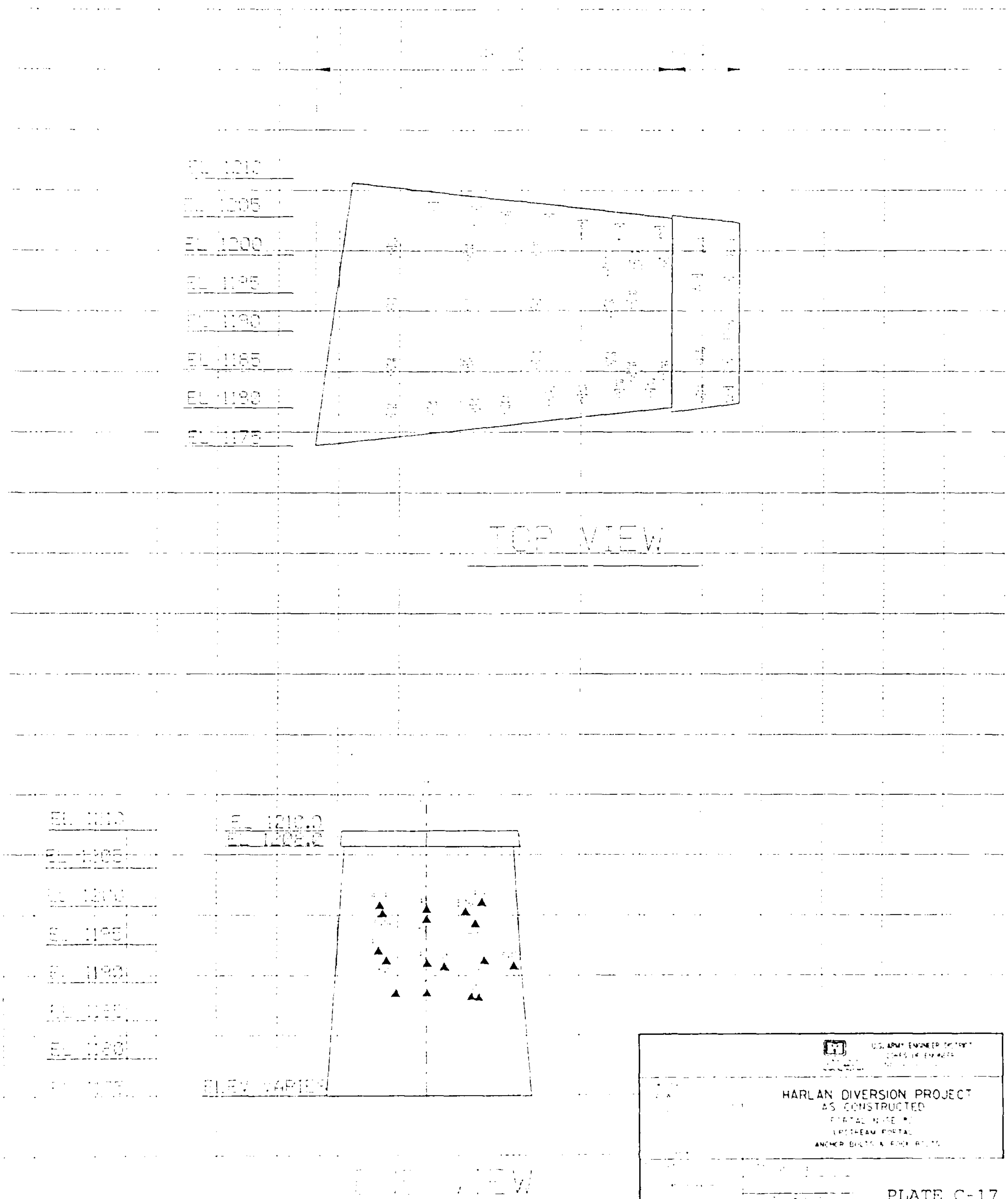
HARLAN DIVERSION PROJECT
AS CONSTRUCTED

PLATE C-16



RIGHT SIDE VIEW

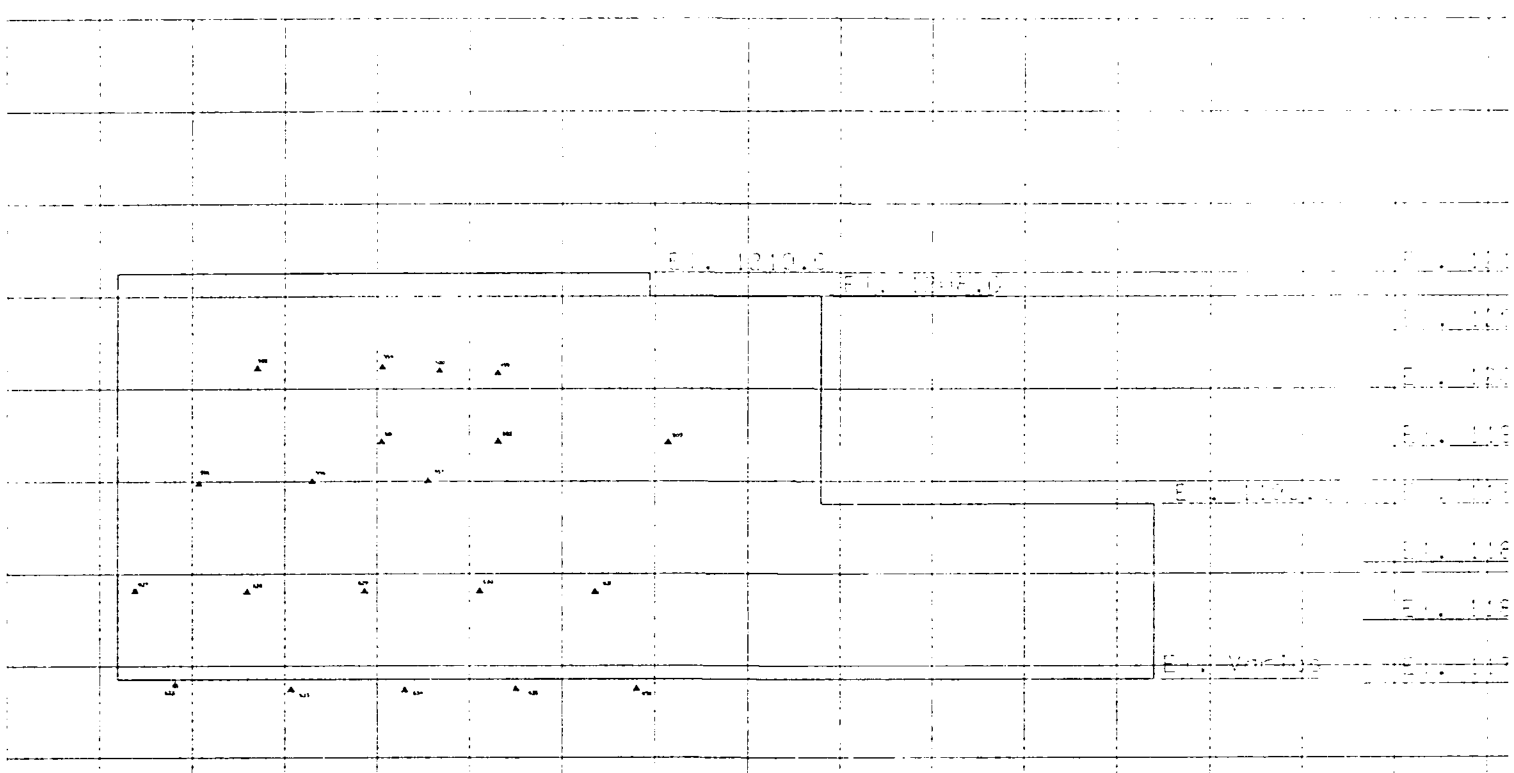




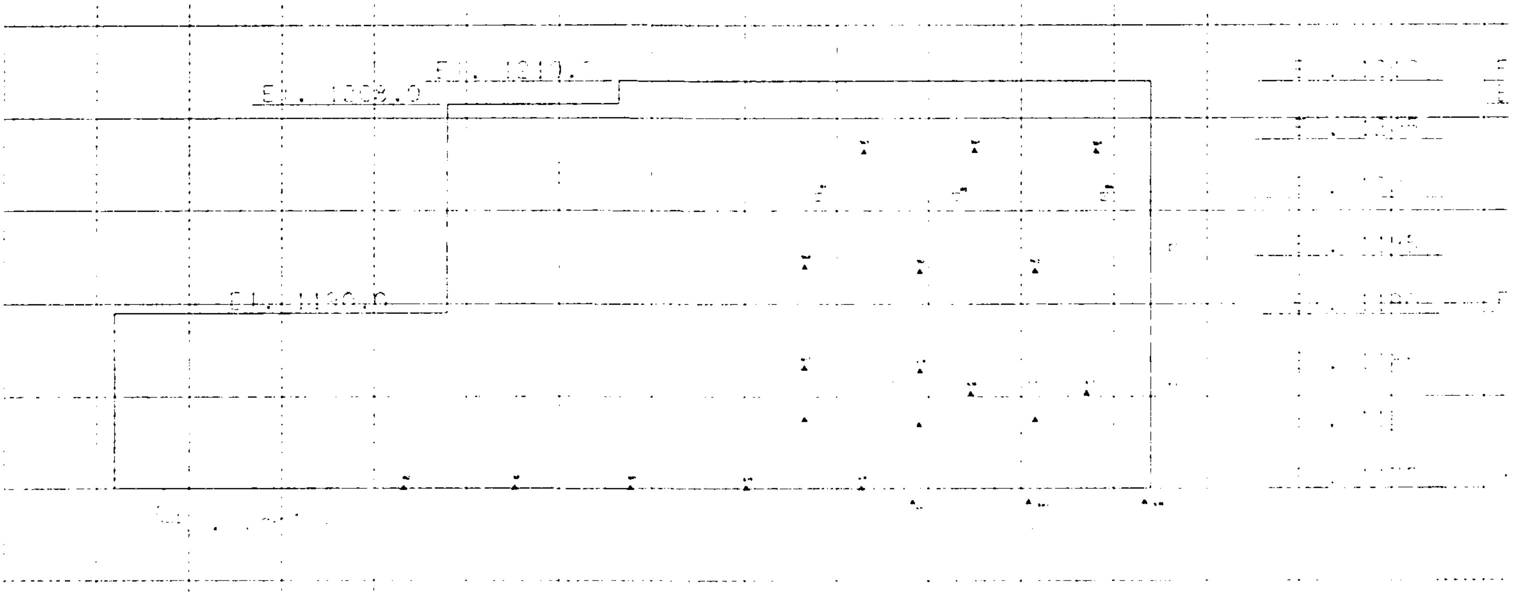
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS

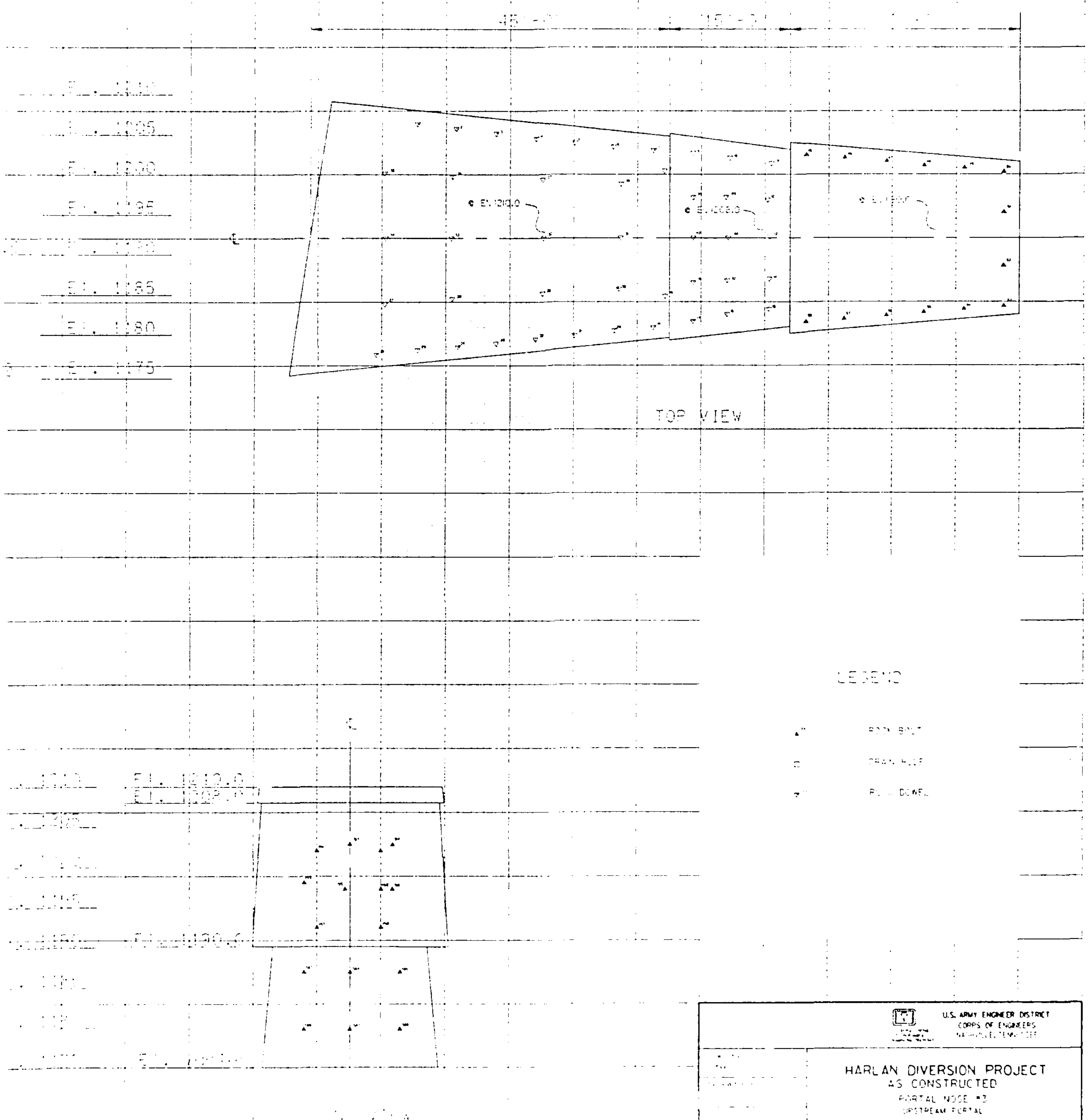
HARLAN DIVERSION PROJECT
AS CONSTRUCTED
UPSTREAM PORTAL
ANCHOR BOLTS & ROCK BOLTS

PLATE C-17



RIGHT SIDE VIEW





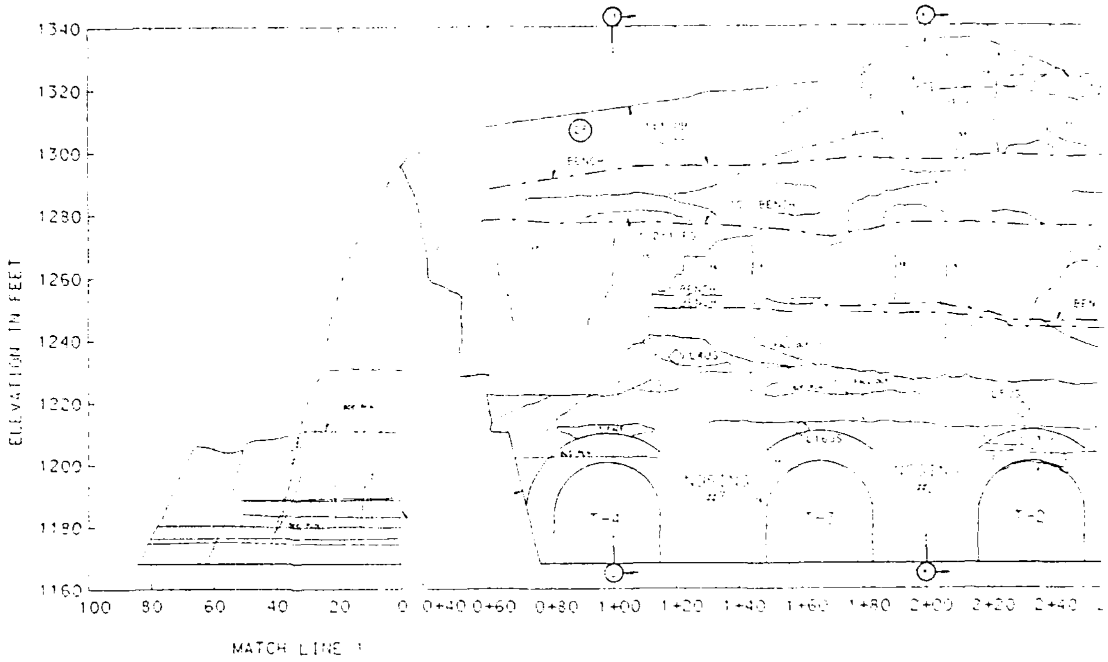
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

HARLAN DIVERSION PROJECT
AS CONSTRUCTED
PORTAL NOSE #3
UPSTREAM PORTAL
ANCHOR BOLTS & ROCK BOLTS

PLATE C-18

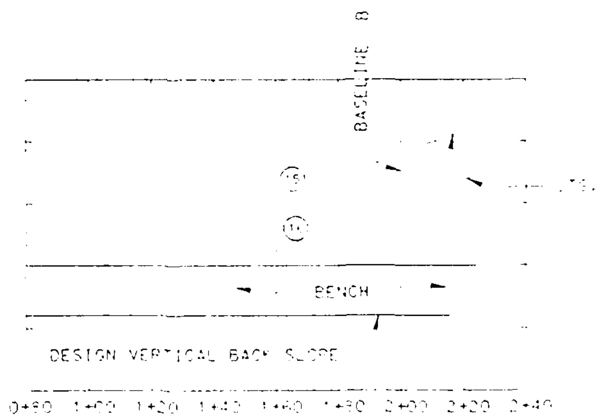
5 4

D

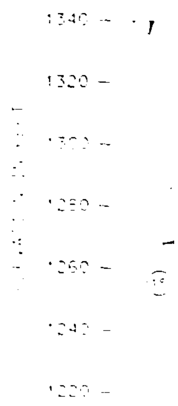


C

B

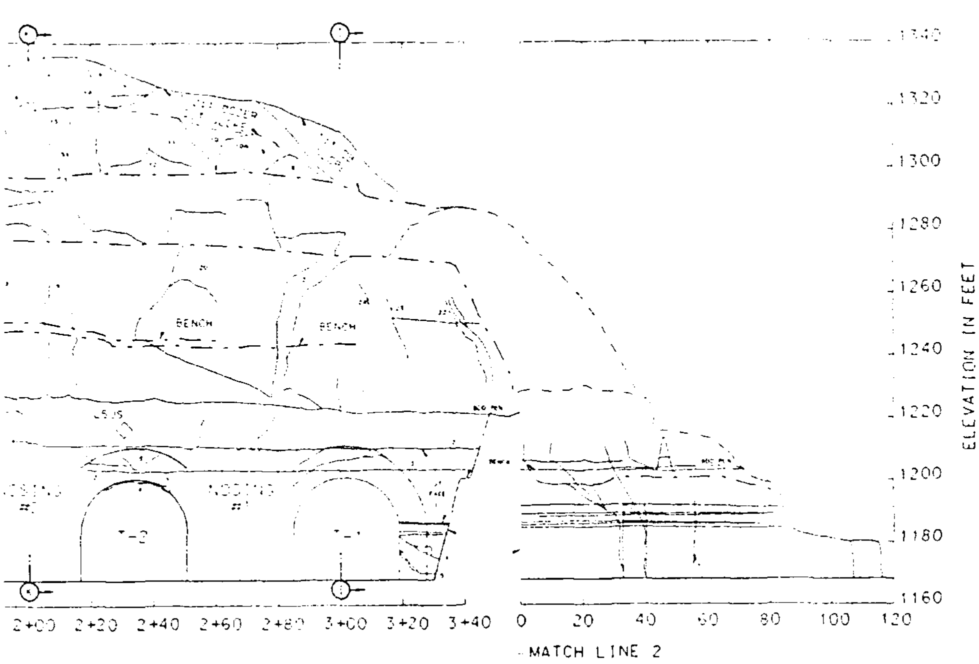


HORIZONTAL SECTION
AT ELEVATION 1260



VE

A



JOINT DESCRIPTIONS

1. Jt face, N5°E 80°SE-N80°E 70°S
2. Jt face, N75°E 70°SE
3. Jt face, Irr, N70°E 75°SE
4. Jt, N60°E, 80°SE
5. Jt, N15°W 85°NE 0⌀
   5a. Jt, N15°E 75°SE
6. Jt, N55°W 70°SW 0⌀
   6a. N40°E 90°
7. Jt, Irr, N80°E 75°SE 0⌀
8. Jt face, Irr, N75°-40°E 90°
9. Jt, N20°W 0⌀
10. Jt, Irr, N10°W 90°
    10a. Jt, N40°E 90°
11. Jt face, Irr, N75°E 90°
12. Jt face, N90°W 80°
13. Jt face, N80°W 70°SW
14. Jt, N45°W 90° 0⌀
15. 16. Jt, N40°E 75°SE 0⌀
17. Jt, N55°W 90° 0⌀
18. Jt, N55°W 80°SW 0⌀
19. Jt, N25°W 40° 0⌀
20. Jt, N40°E 75°SE 0⌀
21. Zone of fls, N40°E 75°SE
22. Zone of fls, N25°E 65°SE 0⌀
23. Jt, N75°W 90°
24. Jt, N80°W 90°

LEGEND

L4US LOAD CELL

T1 BELL JOINT DESCRIPTIONS

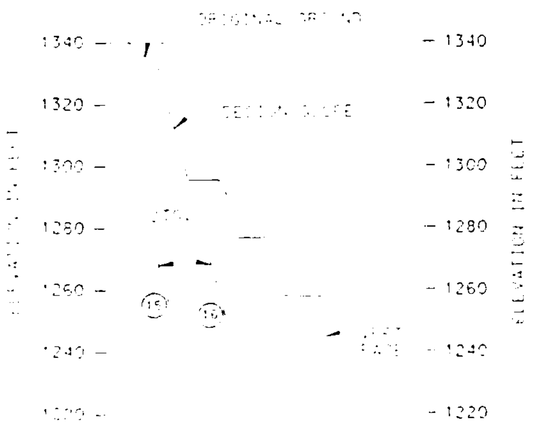
1. Jt, N80°E 75°SE 0⌀
2. 3. Horiz ... 0⌀
4. 5. Jt, N80°E 75°E 0⌀

T2 BELL JOINT DESCRIPTIONS

1. 2. Bdg ... horiz, 0⌀
3. Jt, N80°E 75°SE 0⌀
4. Jt, N50°E 90°-85°SE 0⌀
5. Frac face, N40°E 60°NW

T3 BELL JOINT DESCRIPTIONS

1. Bdg ...
2. ...

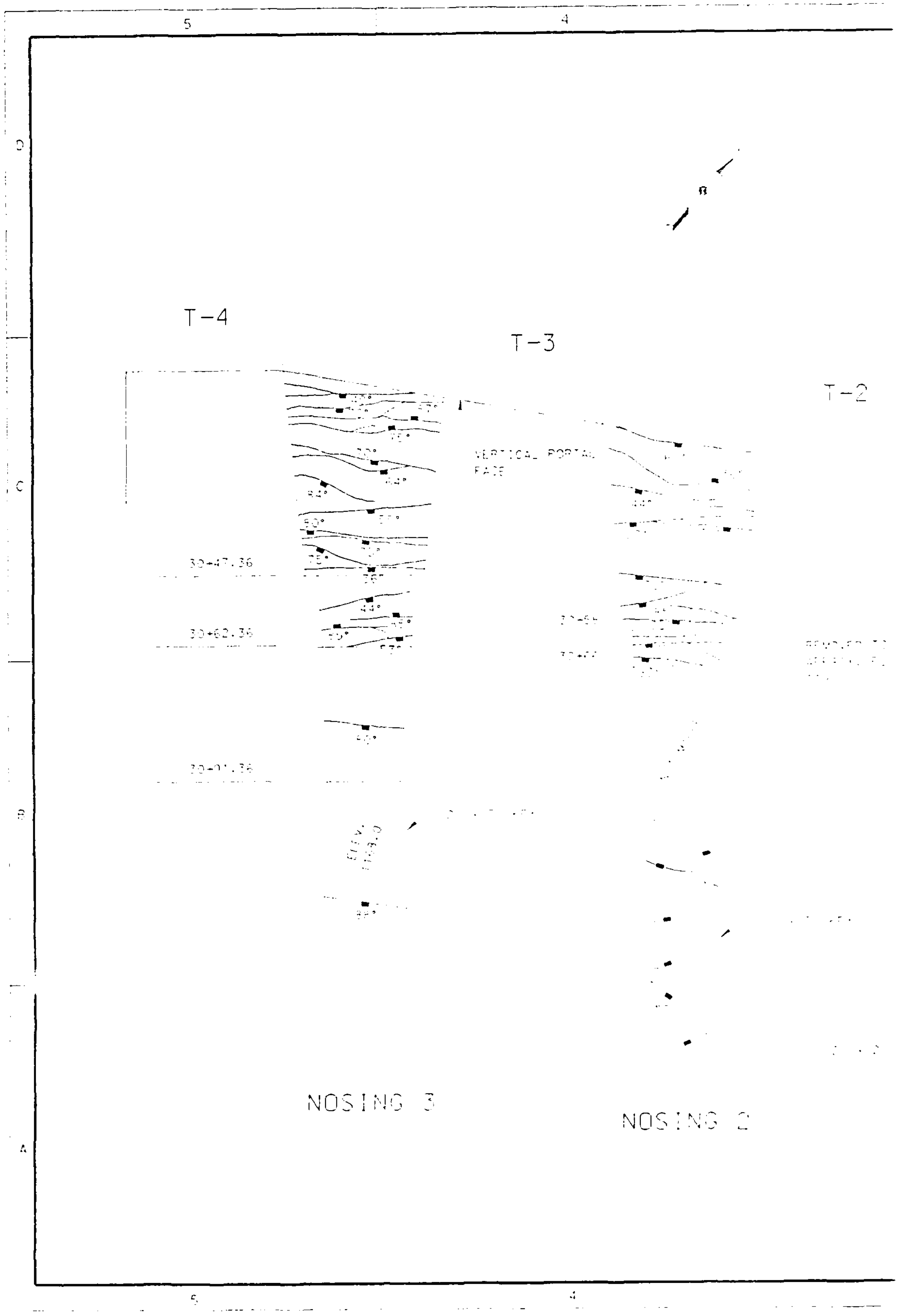


VERTICAL SECTION
AT STATION 2+00

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

UPPER CUMBERLAND RIVER BASIN
LOCAL FLOOD PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION TUNNELS
UPSTREAM PORTAL
GEOLOGIC MAP AND
CROSS-SECTION LOCATIONS

Q1A-4393



T-4
T-3
T-2
VERTICAL PORTAL FACE
30+47.36
30+62.36
30+91.36
NOSING 3
NOSING 2

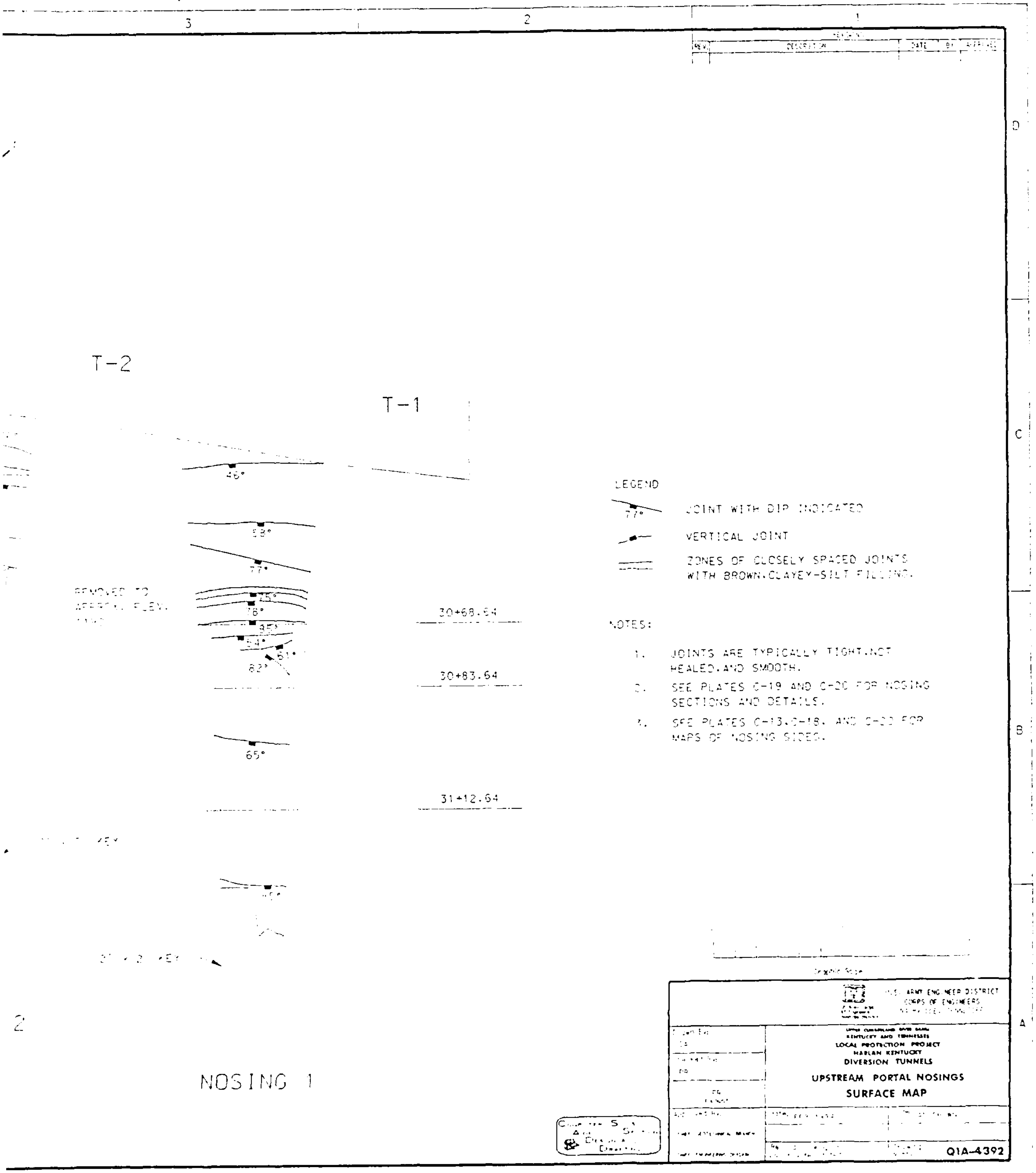
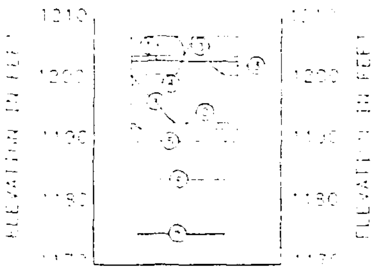
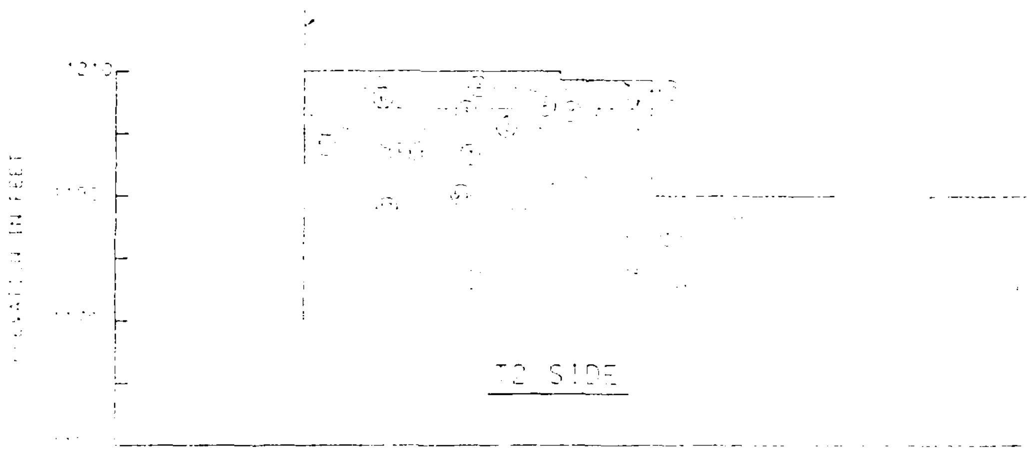

T-2
T-1
46°
58°
77°
75°
78°
85°
54°
61°
82°
65°
30+68.64
30+83.64
31+12.64
LEGEND
77°
JOINT WITH DIP INDICATED
VERTICAL JOINT
ZONES OF CLOSELY SPACED JOINTS WITH BROWN, CLAYEY-SILT FILLING.
NOTES:
1. JOINTS ARE TYPICALLY TIGHT, NOT HEALED, AND SMOOTH.
2. SEE PLATES C-19 AND C-20 FOR NOSING SECTIONS AND DETAILS.
3. SEE PLATES C-13, C-18, AND C-20 FOR MAPS OF NOSING SIDES.
NOSING 1
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN KENTUCKY
DIVERSION TUNNELS
UPSTREAM PORTAL NOSINGS
SURFACE MAP
Q1A-4392

PLATE C-20

N1 (FRONT) JOINT DESCRIPTIONS



N1 FRONT



T2 SIDE

T2 (SIDE)

JOINT DESCRIPTIONS

[illegible]

T1 (SIDE)

JOINT DESCRIPTIONS

[illegible]

LEGEND

EST[illegible]MATED L[illegible] MATER[illegible]AL [illegible]
BLAST[illegible]NG AND[illegible] [illegible]AK MATER[illegible]AL

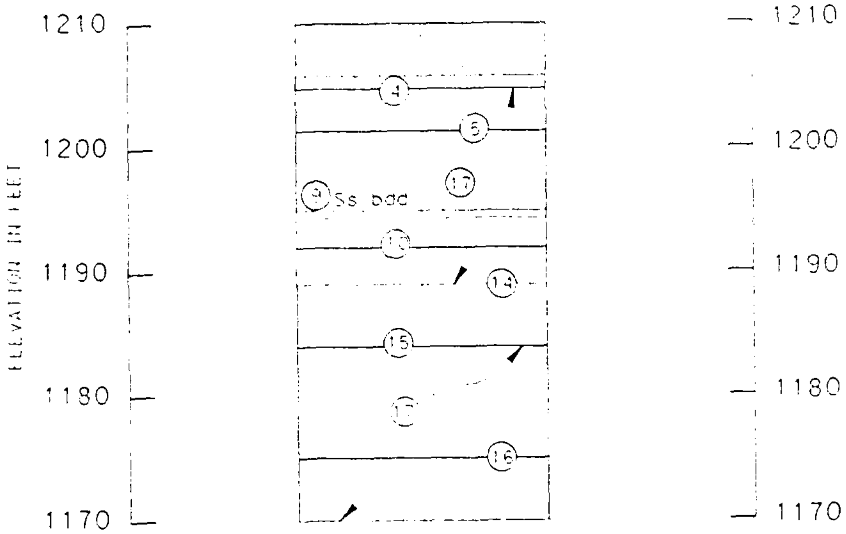
U.S. ARMY ENGINEER DISTRICT

[illegible]

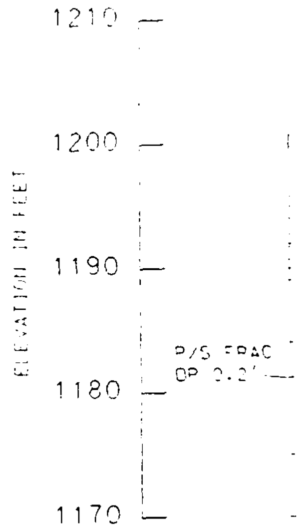
PROFILE MAP

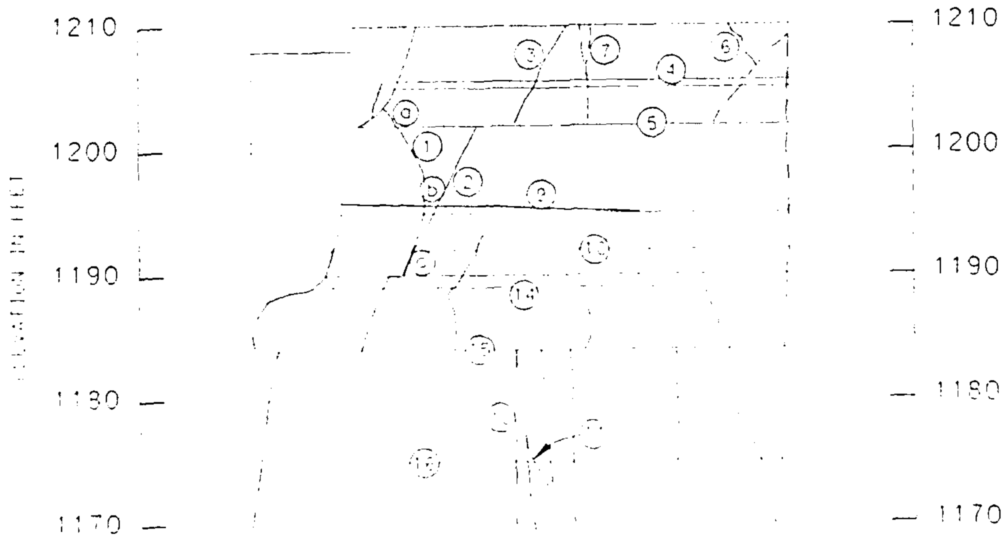
OIA-4/394

PLATE C-21



FRONT

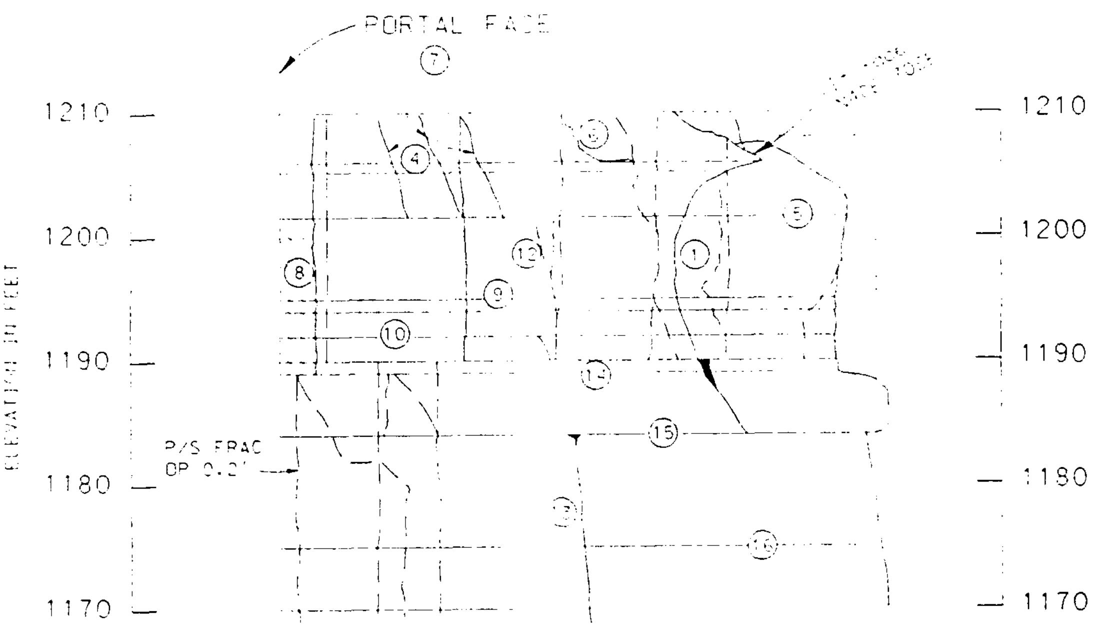




T2 SIDE

JOINT DESCRIPTIONS

1. Jt, irr, op, fe st
   (a) N45°E 46°SE
   (b) N45°E 90°
   c) N45°E 45°NW
2. Jt, ti N45°E 46°SE
3. Jt, op, N45°E 46°SE
4. Ss bdd, hd, v f grd,
5. Bdd pln, op, hor
6. Jt, N50°E
7. Jts, op, fe st, N40°E 60
8. Jts, N40°E 60°SE
9. Ss bdd, hd,
10. Jt, N45°E
11. Jt, op, fe st, N65°E 74°
12. Jt, op, fe st, N65°E 84°
13.
14.
15. Bdd pln, op, hor
16.
17.



T3 SIDE

JOINT DESCRIPTIONS

1. Jt.irr.op.fe st
   (a) N45°E 46°SE
   (b) N45°E 90°
   (c) N45°E 45°NW
2. Jt.ti N45°E 46°SE
3. Jt.op.N45°E 46°SE
4. Ss bdd.hd.v f grd.lt gr
5. Bdd pln.op.hor
6. Jt.N50°E 70°SE
7. Jts.op.fe st.N40°E 60°-75°SE
8. Jts.N40°E 60°SE
9. Ss bdd.hd.v f gr.lt gr
10. Jt.N65°E 74°NW-83°SE.0.04'.fe st
11. Jt.op.fe st.N65°E 74°NW
12. Jt.op.fe st.N65°E 84°SE
13. [illegible]
14. Bdd pln.op.hor
15. Bdd pln.op.hor
16. [illegible]
17. [illegible]

LEGEND

P/S PRESPLIT HOLE FRACTURES

BROKEN BEHIND DESIGN LINES

NOTES:

1. SEE PLATE A-2 FOR GEOLOGIC ABBREVIATIONS.
2. SEE PLATES A-3 THRU A-5 FOR EXPLANATION OF DESCRIPTIVE TERMS.
3. SEE PLATES C-15 AND C-16 FOR NOSING SECTIONS AND DETAILS.

10 0

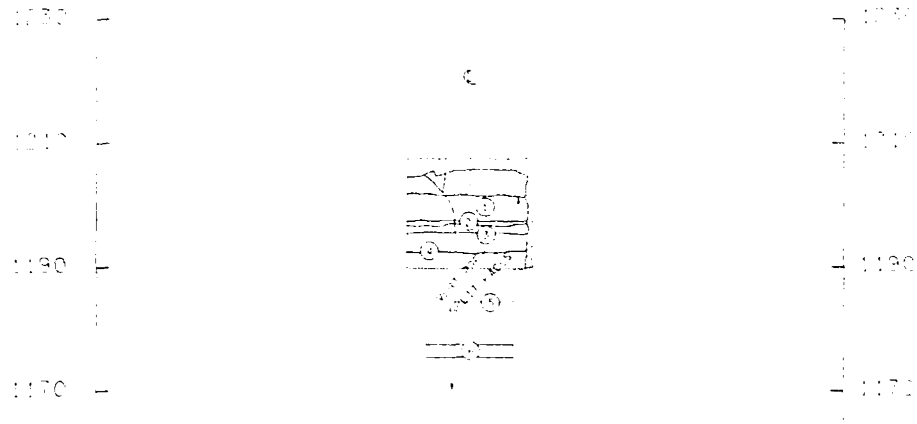
Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

Drawn By: [illegible]
Checked By: P.R.

KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION TUNNELS
UPSTREAM PORTAL NOSING 2
GEOLOGIC MAP

Q1A-4395



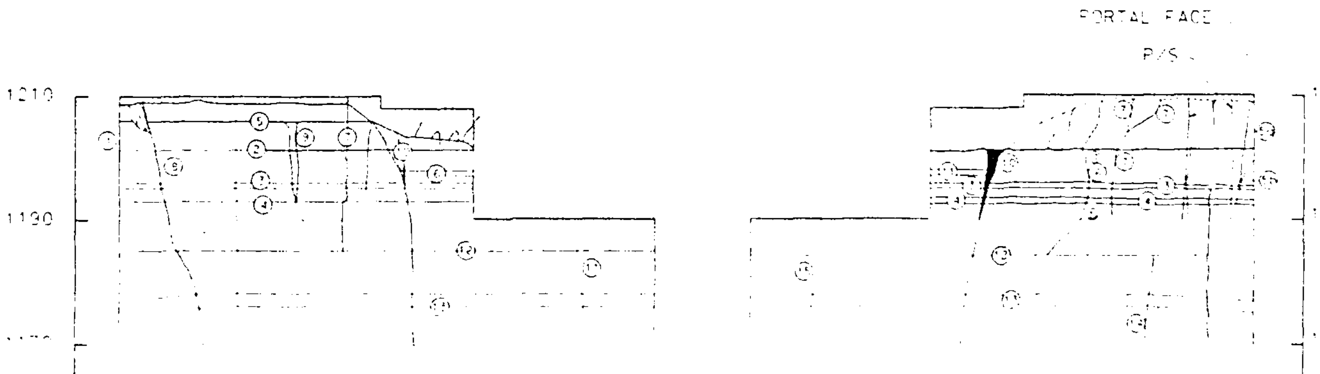
N3 FRONT VIEW

N3 FRONT (JOINT DESCRIPTIONS)

1. Bdd pln, tl,0ø
2. Bdd hor
3. Bdd hor
4. Bdd hor
5. Bdd pln, sl op .01'
6. Bdd-Sis w/Ss strgs sl op .01'

T4 SIDE (JOI

- Bdd pln, ≈ ho
- Bdd ≈ hor
- Bdd pln, ≈ ho
- Bdd pln, ≈ hor
- Bdd ≈ hor
- Pre-ex..., bdd pln, of ≈
- Jt, N45°E
- Jt,
- Jt, to & wea rock
- Jt, N65°E 80°S fe st
- Bdd pln, ≈ hor
- Bdd, Sis w/Ss



T4 SIDE

T3 SIDE

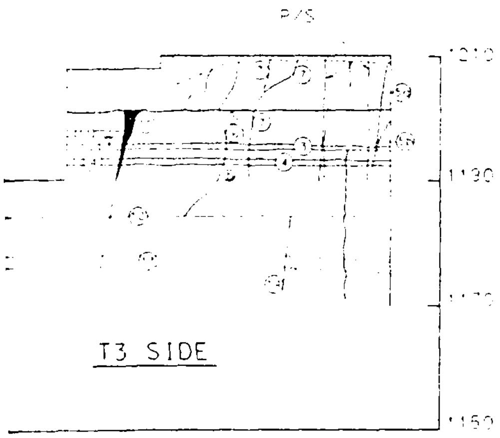
T4 SIDE (JOINT DESCRIPTIONS)

1. shift toward U/S ≈0.05' direction of arrows
2. Bdd pln. ≈ hor. 0r
3. Bdd ≈ hor
4. Bdd pln. ≈ hor
5. Bdd pln. ≈ hor
6. Bdd ≈ hor
7. Pre-split, showing movement along bdd pln. of ≈0.4'
8. Jt. N45°E 74°SE. .04', sl fe st
9. Jt. .05 @ top. 0r @ bottom
   (a) N55°E 85°SE
   (b) N55°E 90°SE
10. Jt. (>1.0 to 0.4 @ bottom)- cl & wea rock mtl-fill
11. Jt. N65°E 80°SE. .05' to (>1.0'), fe st
12. Bdd pln. ≈ hor. .01'
13. Bdd. Sls w/Ss strgs. ≈ hor. .01'

T3 SIDE (JOINT DESCRIPTIONS)

1. Bdd. ≈ hor. lt gr. brk
2. Bdd. ≈ hor. dk gr. to mtl
3. Bdd. Sls/Ss strgs. ≈ hor
4. Bdd. Sls. ≈ hor
5. Jts. .01, possibly due to blasting
   (a) N60°E 85°SE
   (b) N60°E 75°SE
6. Jt. N45°E 63°NW
7. Frac possibly due to P/s
8. Jts. curved. .05
   (a) N65°E 65°NW
   (b) N65°E 50°SE
9. Jt. N456E 60°SE
10. Jt. N80°E 65SE ≈90°. 0r. >1.0' near top. 0.4' @ bottom. cl & wea rock frags-fill
11. Bdd. ≈ hor
12. Bdd pln. .01'
13. Bdd. Sls w/Ss strgs
14. Jt. N65°E 85°SE. 03'. fe st
15. Jt. N656E 826Se. .05' (>1.0') fe st

PORTAL FACE



T3 SIDE

Graphic Scale

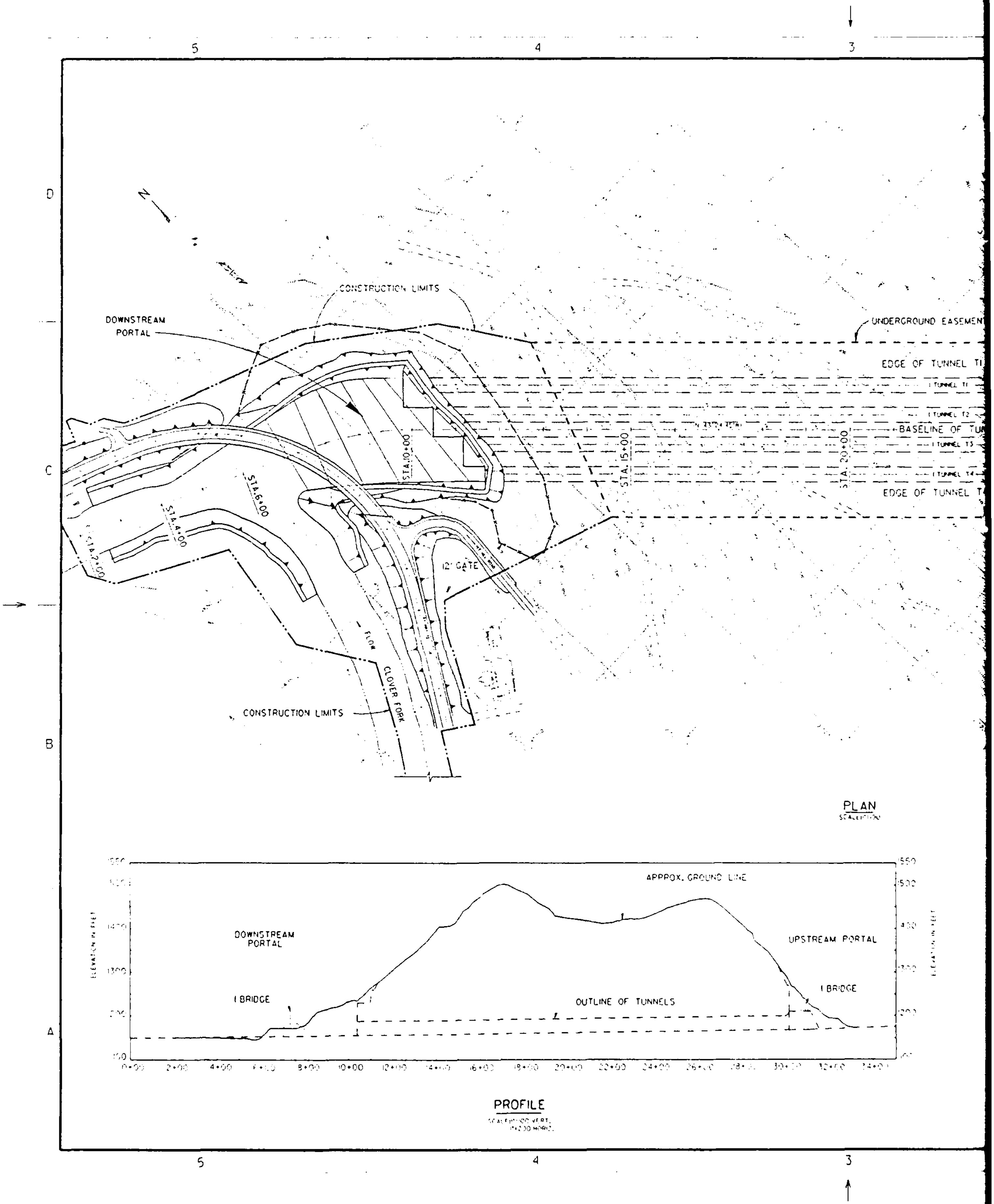
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

Drawn By: D.A.G.	UPPER CUMBERLAND RIVER BASIN KENTUCKY AND TENNESSEE LOCAL PROTECTION PROJECT HARLAN, KENTUCKY DIVERSION TUNNELS
Checked By: P.P.	UPSTREAM PORTAL NOSING 3 GEOLOGIC MAP
Approved By:	Date: FEB 1994
CHIEF, GEOTECHNICAL BRANCH	
CHIEF, ENGINEERING DIVISION	Drawing Number: Q1A-4396

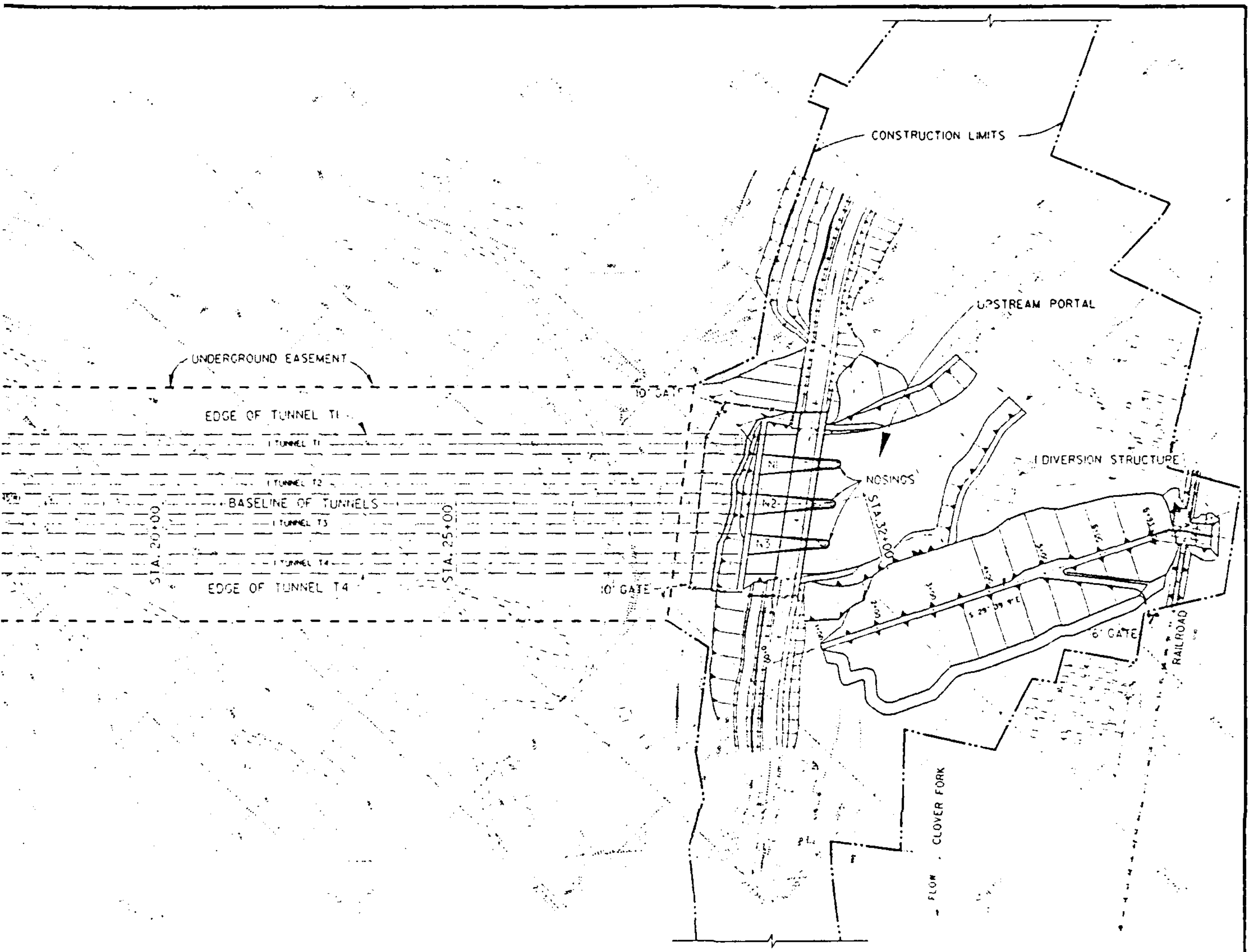
Computer Soils Aided Section Design & Drafting

Appendix D - Tunnels

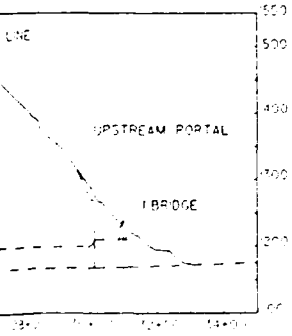
Plate No.	Drawing No.	Description
D-1	Q1A-64/2.3	General Plan
D-2	Q1A-64/6.2	Boring Plan
D-3	Q1A-64/30.2	Section A-A
D-4	Q1A-64/31.1	Section B-B
D-5	Q1A-64/71.1	Plan, Section, and Profile
D-6	Q1A-64/72.2	Support Details
D-7 thru D-27	----	Tunnel 1 Maps
D-28 thru D-47	---	Tunnel 2 Maps
D-48 thru D-67	---	Tunnel 3 Maps
D-67 thru D-85	---	Tunnel 4 Maps



CONSTRUCTION LIMITS
DOWNSTREAM PORTAL
UNDERGROUND EASEMENT
EDGE OF TUNNEL T1
BASELINE OF TUN
EDGE OF TUNNEL T
STA. 2+00
STA. 4+00
STA. 6+00
STA. 10+00
STA. 15+00
STA. 20+00
12' GATE
FLOW
CLOVER FORK
CONSTRUCTION LIMITS
PLAN
APPROX. GROUND LINE
DOWNSTREAM PORTAL
UPSTREAM PORTAL
BRIDGE
BRIDGE
OUTLINE OF TUNNELS
PROFILE



PLAN



NOTES:

1. ALL ELEVATIONS ARE IN FEET AND REFER TO NATIONAL GEODETIC VERTICAL DATUM (NGVD).
2. FOR DETAILED PLANS OF THE PORTALS, SEE DRAWINGS OIA-64/51 AND 61.
3. FOR DETAILED PLANS OF THE DIVERSION STRUCTURE, SEE DRAWING OIA-64/73.
4. FOR DETAILED PLANS OF ROAD RELOCATIONS AND BRIDGES, SEE SEPARATE FOLIO.
5. LOCATION OF FENCING SHOWN IS APPROXIMATE. FINAL LOCATION OF FENCING SHALL BE AS APPROVED BY THE CONTRACTING OFFICER.

LEGEND

- - - - - - - UNDERGROUND EASEMENT
———-··——— CONSTRUCTION LIMITS

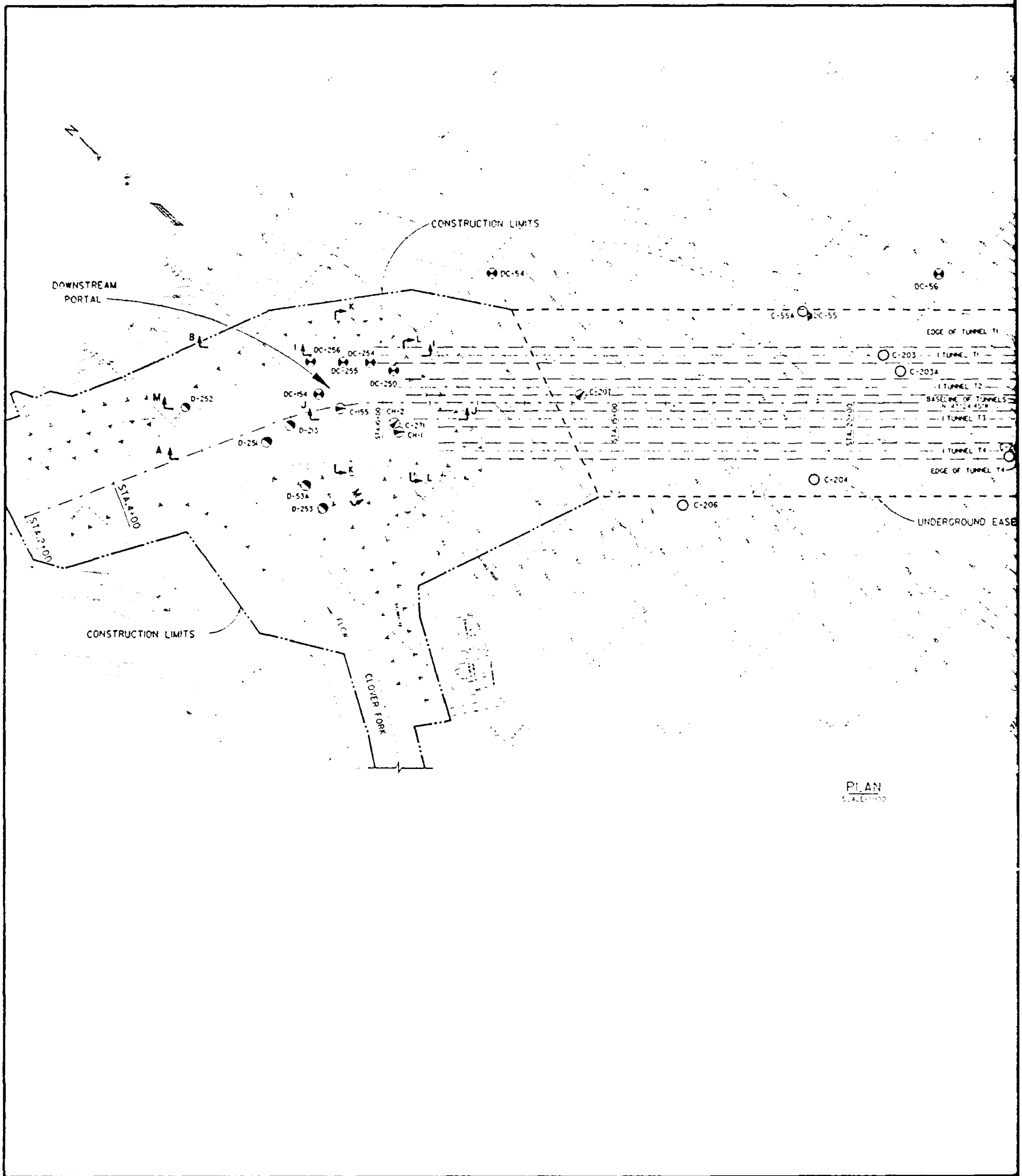
3	10-6-93	AS BUILT FENCES	S.B.D.	
2	7-6-89	REVISED CONSTRUCTION LIMITS AND UPSTREAM PORTAL	A.G.	
1	5-31-89	CONFORMING TO REVIEW COMMENTS	R.J.	

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

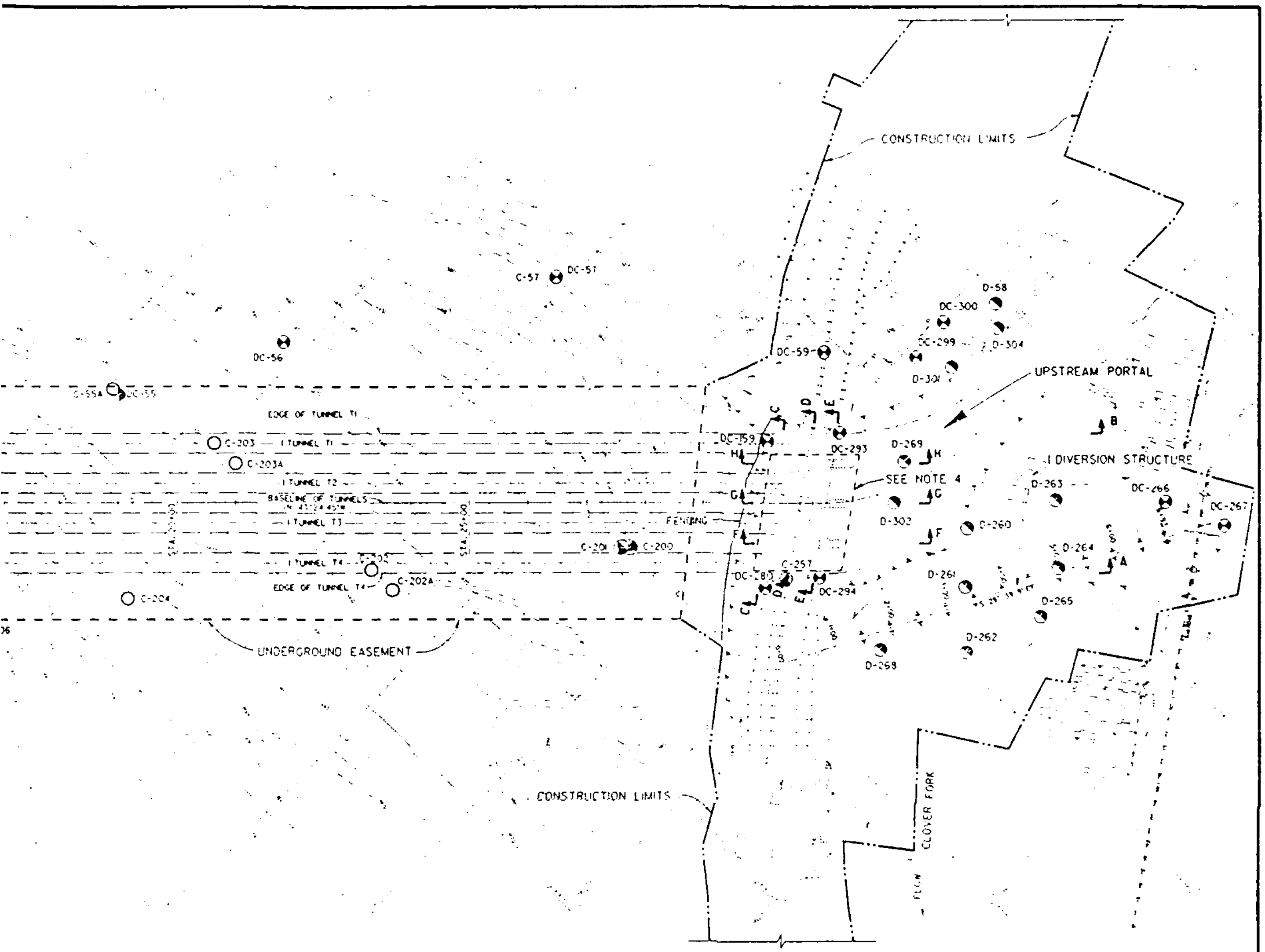
DIVERSION TUNNELS
GENERAL PLAN

OIA-64/2.3

PLATE D-1



CONSTRUCTION LIMITS
DOWNSTREAM PORTAL
DC-54
DC-56
C-55A
DC-55
EDGE OF TUNNEL T1
C-203
C-203A
DC-256
DC-254
DC-255
DC-250
DC-154
C-155
CH-2
C-271
CH-1
C-207
D-252
D-213
D-251
STA.15+00
STA.20+00
EDGE OF TUNNEL T4
C-204
C-206
D-53A
D-253
STA.4+00
STA.2+00
UNDERGROUND EASE
CONSTRUCTION LIMITS
CLOVER FORK
PLAN



PLAN

NOTES

1. ALL ELEVATIONS ARE IN FEET AND REFER TO NATIONAL GEODETIC VERTICAL DATUM (NGVD)
2. FOR DETAILED PLANS OF THE PORTALS, SEE DRAWINGS OIA-64/51 AND 61
3. FOR DETAILED PLANS OF THE DIVERSION STRUCTURE.SEE DRAWING OIA-64/73.
4. FOR BORING LOCATIONS IN UPSTREAM PORTAL AREA.SEE DRAWING OIA-64/32.
5. FOR DETAILED PLANS OF ROAD RELOCATIONS. SEE SEPERATE FOLIO.

2	7-12-89	REVISED CONSTRUCTION LIMITS AND	C.A.G.	J.L.S.
1	5-31-89	CONFORMING TO REVIEW COMMENTS	C.A.G.	J.L.S.

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

DIVERSION TUNNELS
BORING PLAN

OIA-64/6.2

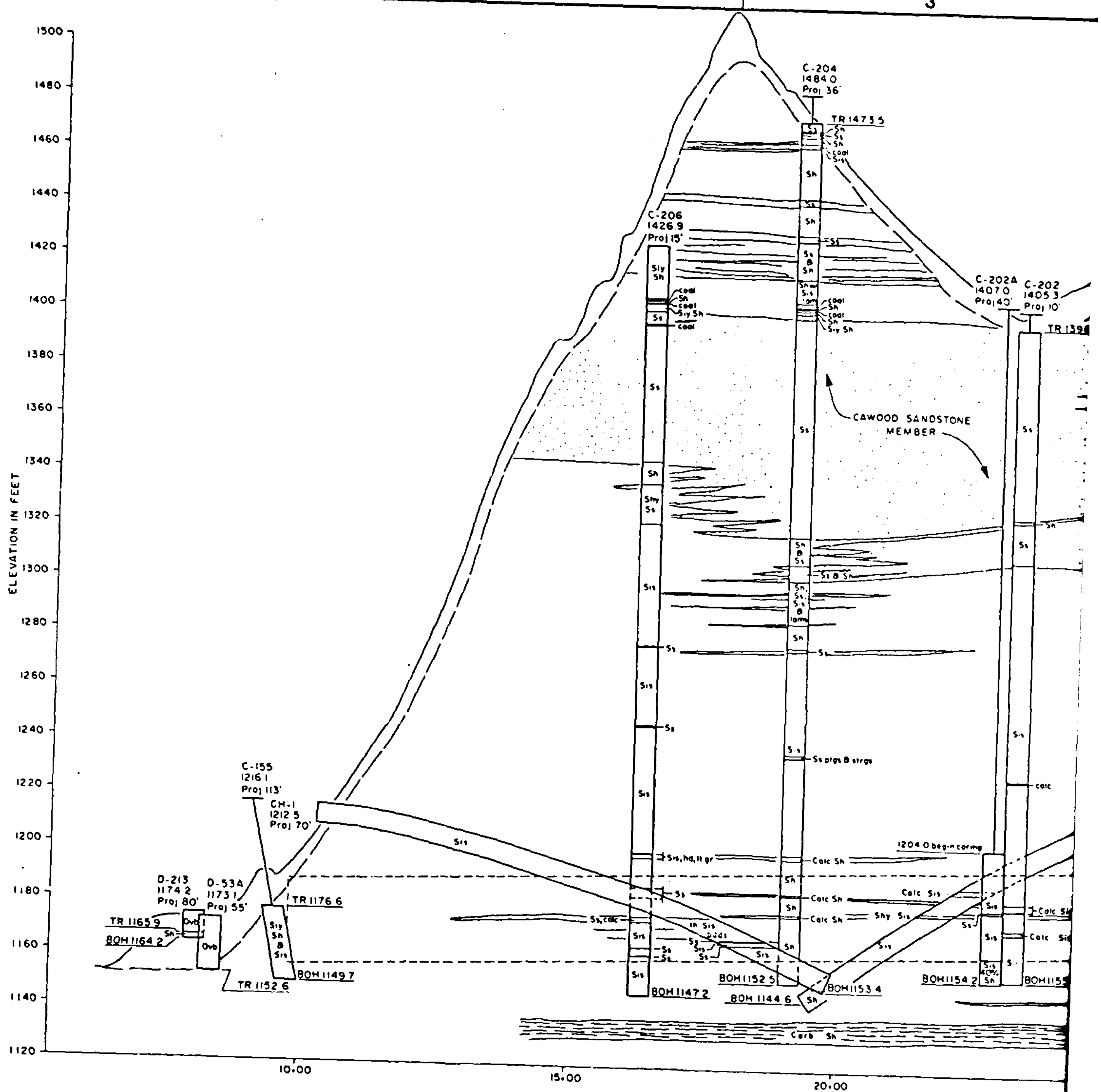
5 | 4 | 3

D

C

B

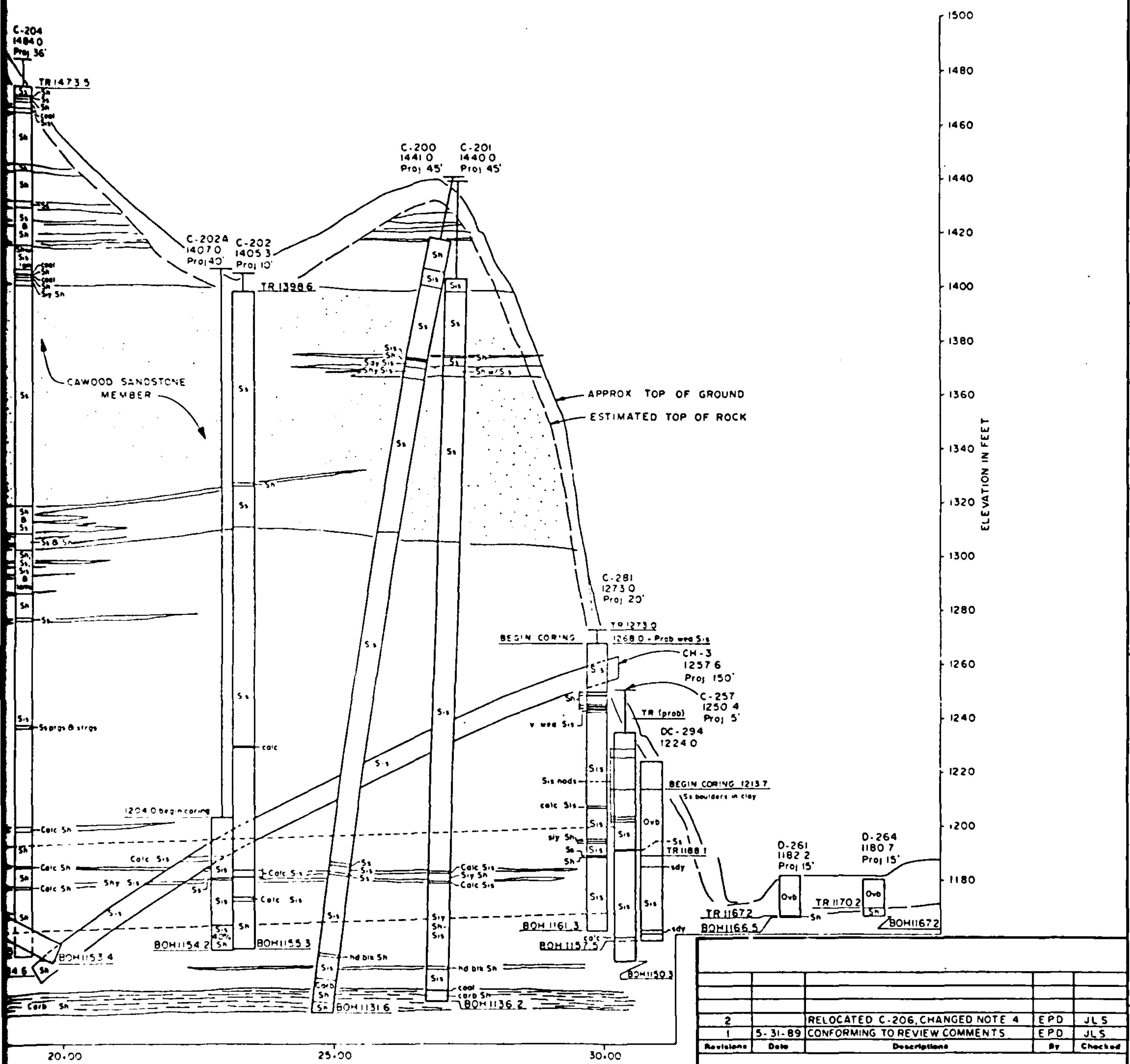
A



SECTION A-A
SCALE HORIZ 1" = 100'
VERT 1" = 20'

NOTES
1 FOR LOCAT
2 ALL ELEV
3 FOR BORIN
4 THESE LO
DETAILED

5 | 4 | 3



SECTION A-A

SCALE HORIZ 1"=100'
VERT 1"=20'

NOTES

1 FOR LOCATION OF SECTION, SEE DRAWING QIA-64/6
2 ALL ELEVATIONS REFER TO MEAN SEA LEVEL
3 FOR BORING LEGEND AND NOTES, SEE DRAWING QIA-64/5
4 THESE LOGS PRIMARILY SHOW LITHOLOGIC DATA. FOR DETAILED INFORMATION, SEE LOGS OF BORINGS

Revisions	Date	Descriptions	By	Checked
2		RELOCATED C-206, CHANGED NOTE 4	EPD	JLS
1	5-31-89	CONFORMING TO REVIEW COMMENTS	EPD	JLS

Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE TENNESSEE

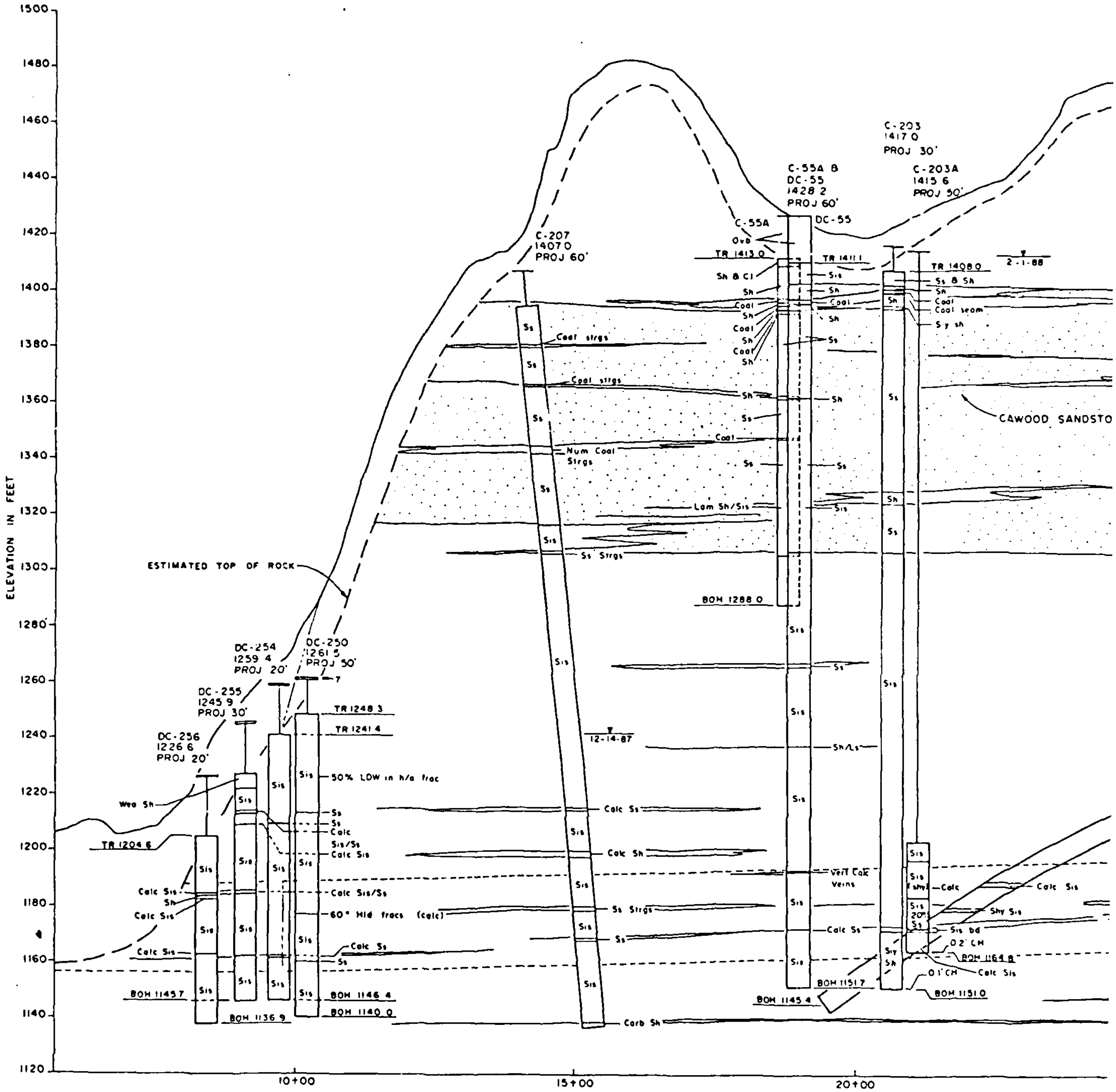
Designed by:
Drawn by:
Checked by:
Approved by:

US Army Corps of Engineers Nashville District

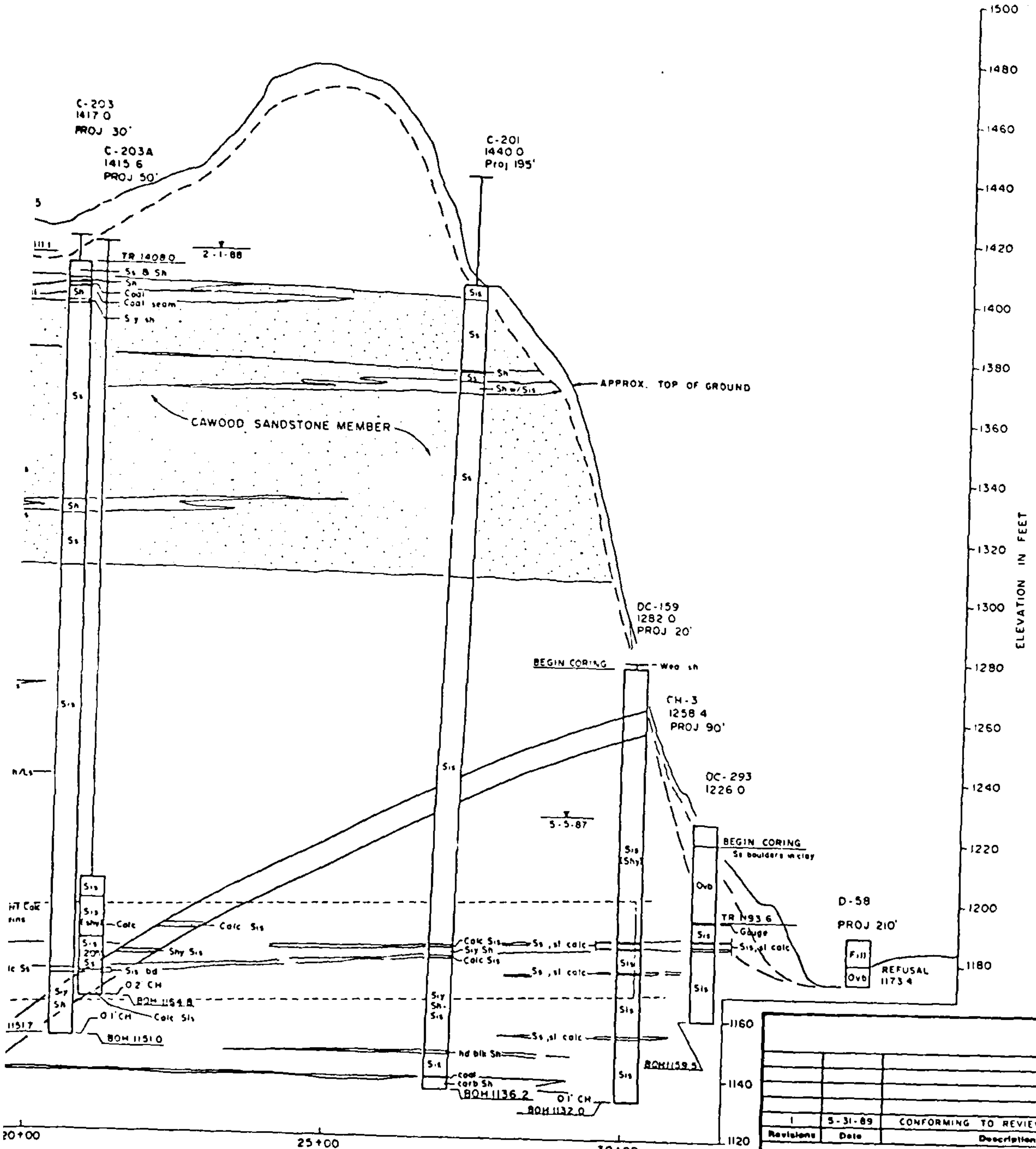
UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY

SECTION A-A

Date:
Sheet ___ of ___
Scale:
Drawing Number QIA-64/30.2
Record Drawing as constructed dated



SECTION B-B
SCALE HORIZ 1" = 100'
VERT 1" = 20'



SECTION B-B
SCALE HORIZ 1" = 100'
VERT 1" = 20'

NOTE:
FOR NOTES, SEE DRAWING QIA-64/30.

Revisions	Date	Descriptions	By	Checked
1	5-31-89	CONFORMING TO REVIEW COMMENTS	CAG	JLS

Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY

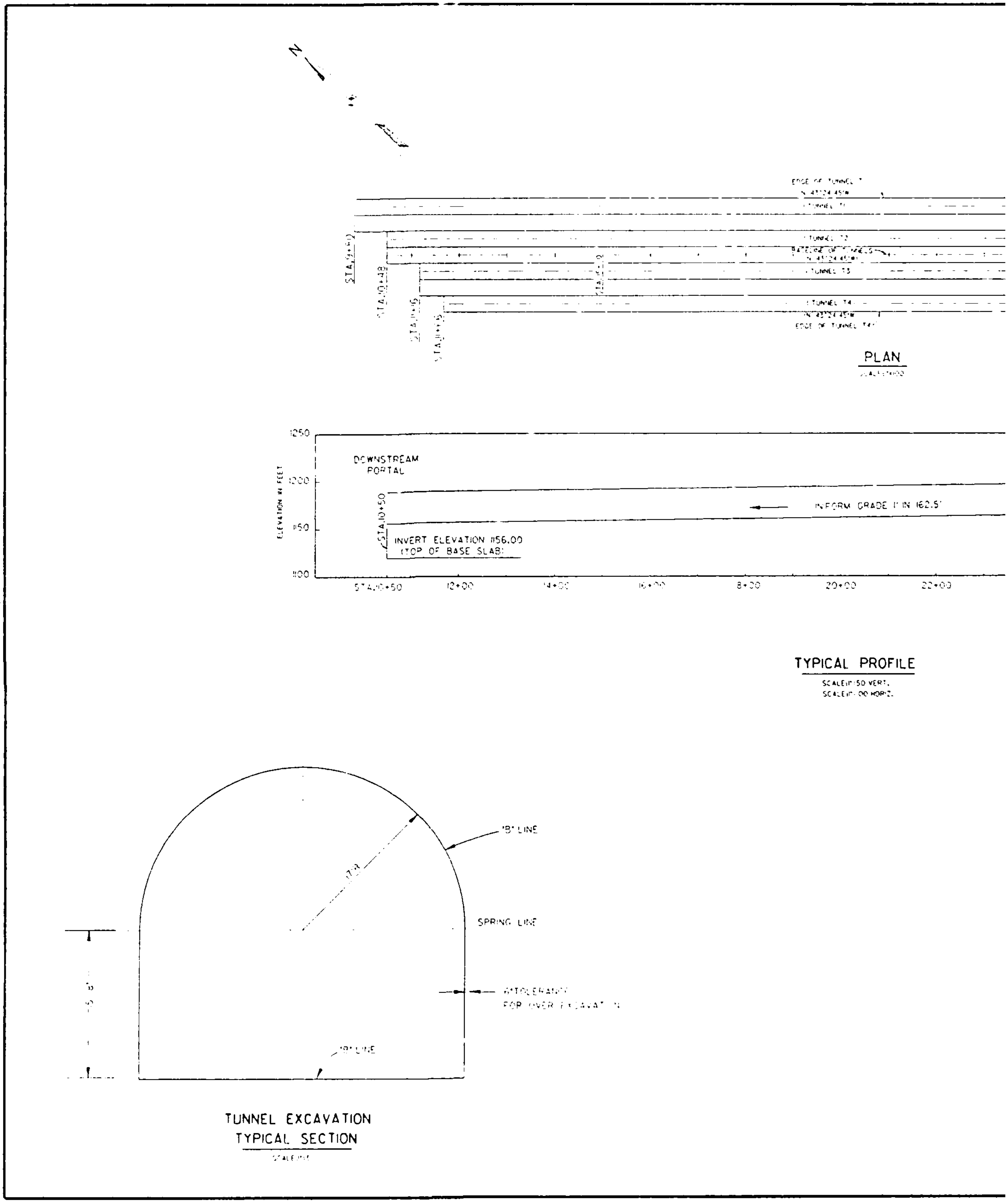
SECTION B-B

Designed by: John L. [signature]
Drawn by: [initials]
Checked by: [initials]
Approved by: [signature]

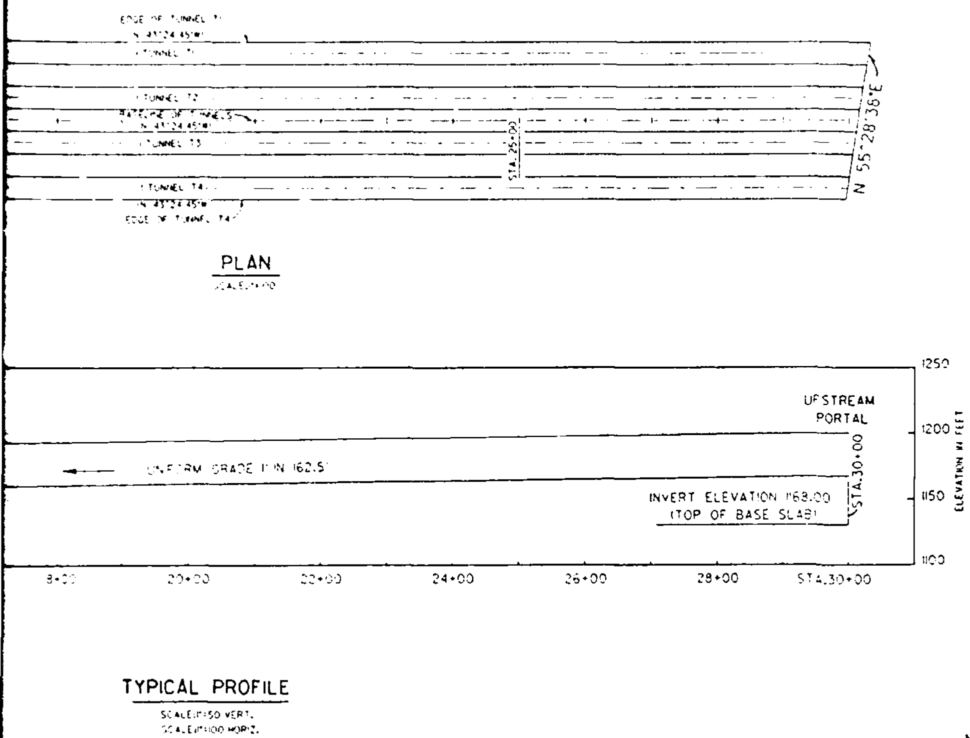
Date:
Sheet _ of _
Scale:
Drawing Number: QIA-64/31.1

Record Drawing as constructed dated

PLATE D-4



PLAN
DOWNSTREAM PORTAL
ELEVATION IN FEET
1250
1200
1150
1100
STA.10+50
12+00
14+00
16+00
18+00
20+00
22+00
UNIFORM GRADE 1' IN 162.5'
INVERT ELEVATION 1156.00
(TOP OF BASE SLAB)
TYPICAL PROFILE
'B' LINE
SPRING LINE
TUNNEL EXCAVATION
TYPICAL SECTION



NOTE

1. FOR GENERAL PLAN OF PROJECT. SEE DRAWING 01A-64/2.

1	5-31-89	CONFORMING TO REVIEW COMMENTS	C.A.G.	J.L.S.

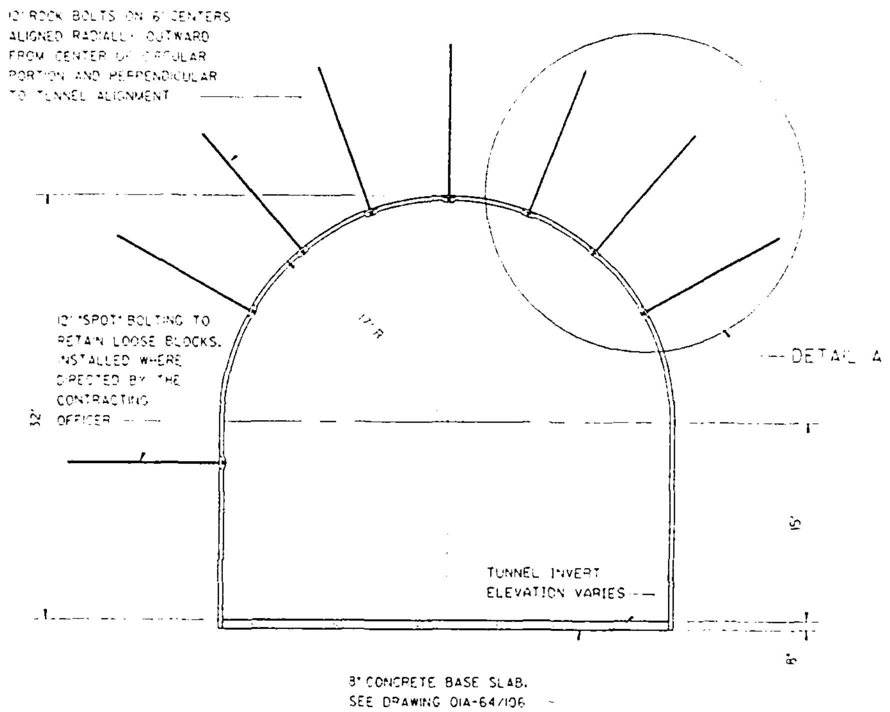
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

DIVERSION TUNNELS

PLAN, SECTION, AND PROFILE

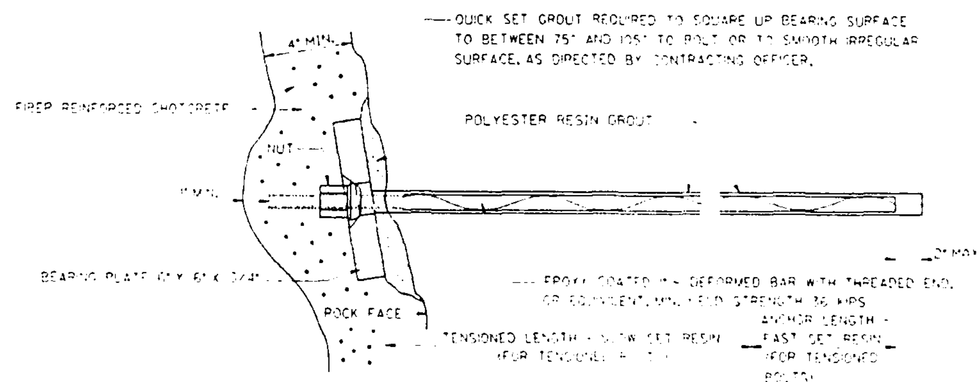
(GEOMETRY)

01A-64/71.1



SECTION

SCALE: 1" = 5'

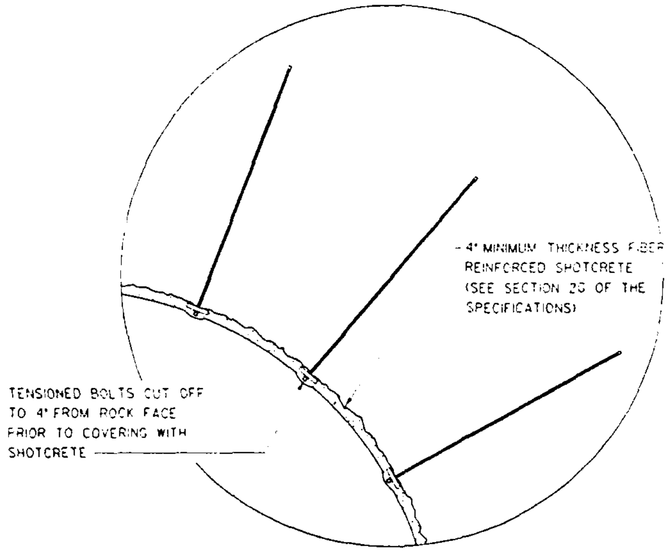


ROCK BOLT DETAIL

NOTE:

CONICAL NUT DETAIL OR OTHER SYSTEM AS APPROVED MAY BE USED.

TENSIO
TO 4'
PRIOR
SHOTCR



DETAIL A
SCALE: 1" = 3'

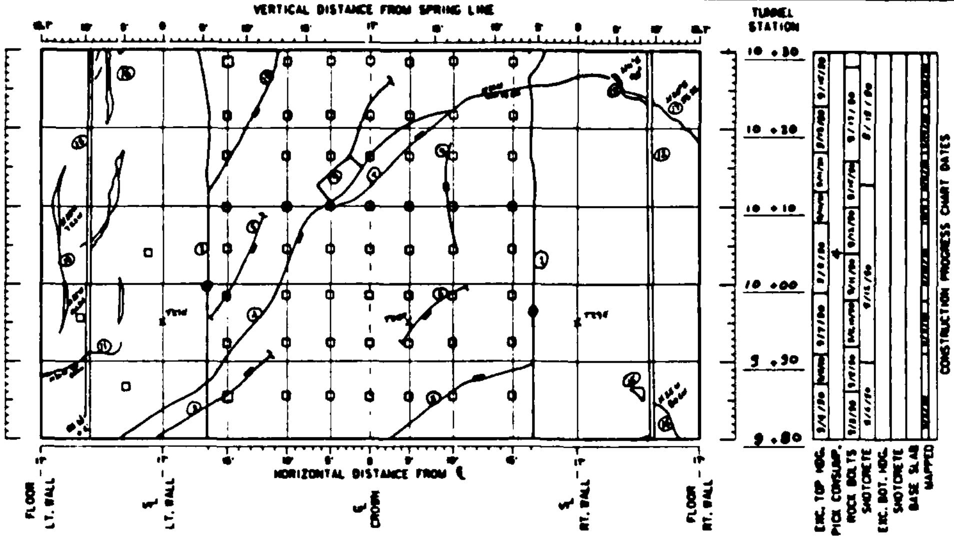
2	2-0-94	AS CONSTRUCTED	MAR	
1	5-30-89	CONFORMING TO REVIEW COMMENTS	E.P.D.	J.L.S.

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

SUPPORT DETAILS

OIA-64/72.2

PLATE D-6



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION	
1	Bdd Jt	[illegible]	C6?, 01, T0, HL9, R5, M	Nearly horizontal
2	Jt		C3, 03, T3, HL9, R5	N10W 70SE
3	Jt		C3, 03, T0, HL9, R6	N35W 80NE
4	Jt		M3, W1, C3, 00, T1, HL9, R6, M9	N10W 83SW
5	Jt		C3, 00, T0, HL4, R4, M3	N10W 80SW
6	Jt		C3, 00, T0, HL9, R9, M1	
7	Jt	[illegible]	C3, 03, T5, HL9, R3, M9	N05E 82SE
8	Jt			N40W 90
9	Spall		6' x 4' Parallelogram, 6" Deep	
10	Jt		C3, 00, T3, HL9, R6, M1	N20E 78NW
11	Jt	[illegible]	00, T4, HL9, R9	N30W 65SW
12	Sh bd		VHd, V F gr, med. gry	

13-18 See Remarks, Sheets 2 and 3

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full perimeter method.
Orientation of strike symbols approximate.
[illegible] dolomite 'pod' [illegible] = 2050 PSI
[illegible] Tunnel down - change cutting head
[illegible] Tunnel [illegible] - installing [illegible] in T-1

[illegible] Bottom heading station [illegible] excavated by roadheader, station [illegible] was blasted

13 Jt 04, T6, R5, HL9, N85W, 70SW
14 Jt 00, T6, N85W, 85SW

SCALE 1" = 10'

Geology By / Drawn By / Checked By / Date

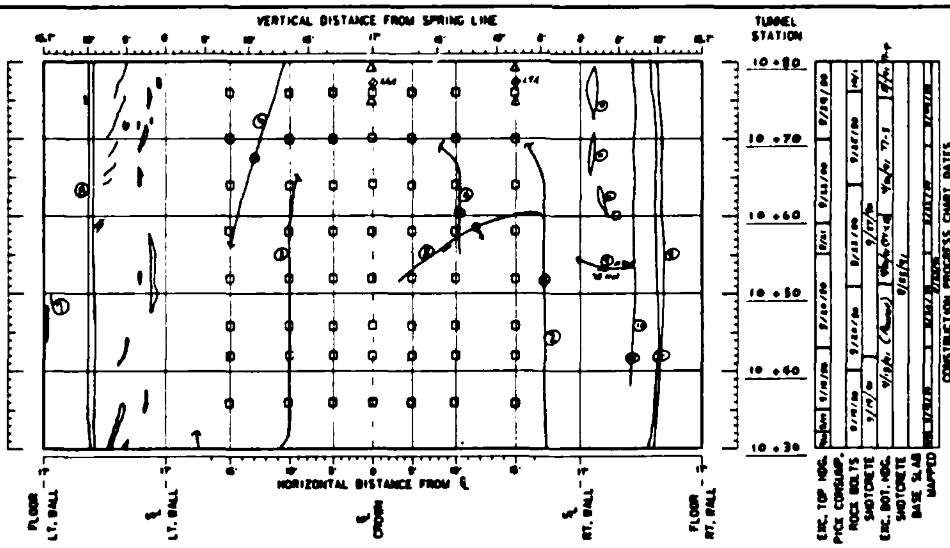
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 1

STATION 9 + 80 TO 10 + 30

SHEET 1 of 42



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T1-1 thru T1-4

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION	
1	Jt	[illegible]	C4, 01, T1, HL9, M0	Nearly horizontal
2	Bdd Jt	[illegible]	C4, 01, T1, HL9, M9	Nearly horizontal
3	Jt	[illegible]	C3, 00, T0, HL4, R5, M3	NEW 75SW
4	Bed pln	[illegible]	C3, T1, HL9, R5, M9	Nearly horizontal
5	Bed pln	[illegible]	C3, T1, HL9, R5, M9	Nearly horizontal
6	Jts	[illegible]	[illegible] 04, T4, R5, HL4, M3	N 29°W 49°SW
7	Jts		[illegible] 04, T4, R5, HL9, M3	N 34°W 68°SW
8	Sh bd		VHd, V F gr, med gray	
9	Jt	[illegible]	C3, 00, T4, HL9, R5, M5 N25E, 75NW	
10	Bed pln	[illegible]	C3, T1, HL4, R5, M9	Near horizontal
11	Cly [illegible]	[illegible]	Cly, [illegible]	

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full perimeter method.
Orientation of strike symbols approximate.
[illegible] - Cut bottom heading with Paurat roadheader from 9+80 to 10+51
[illegible] Bottom hole 10+60, right side

Description from Sheet 1:
15 Jt [illegible] N65W, 80SW
16 Jt, 04, T4, R5, HL9, M1, N80W
17 Jt, N0E, 50E 30
18 Jt, 01, T4, R5, M0, HL4, NNE, 90°

SCALE 1" = 10'

Geology By / Drawn By / Checked By / Date

US Army Corps of Engineers

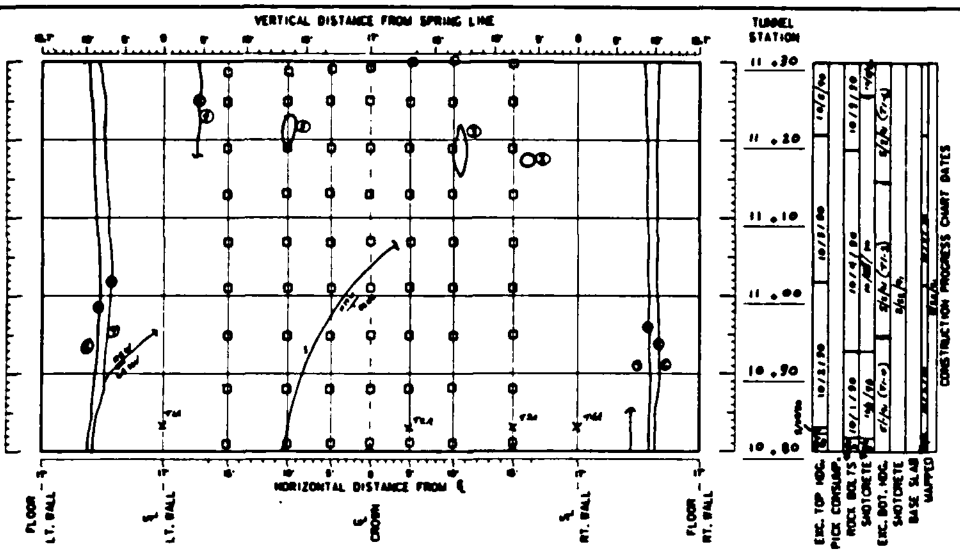
HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 1

STATION 10 + 30 TO 10 + 80

SHEET 2 of 42

PLATE D-7



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T1-4 through T1-5.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd pln	Tim Sby	C3, O1, T3, HL9, M1 N17W 89NE
2	Cone hole		Exposed in wall N... w/o 37° plunge
3	Lens		Ss bounded w/[illegible]
4	Bdd pln		Bdd pln
5	Lens		Ss/[illegible] football-shaped lens
6,7	Cgrn bed	Tim Sby	Silt, cgm, [illegible], HL, ..., B3, near horizontal

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

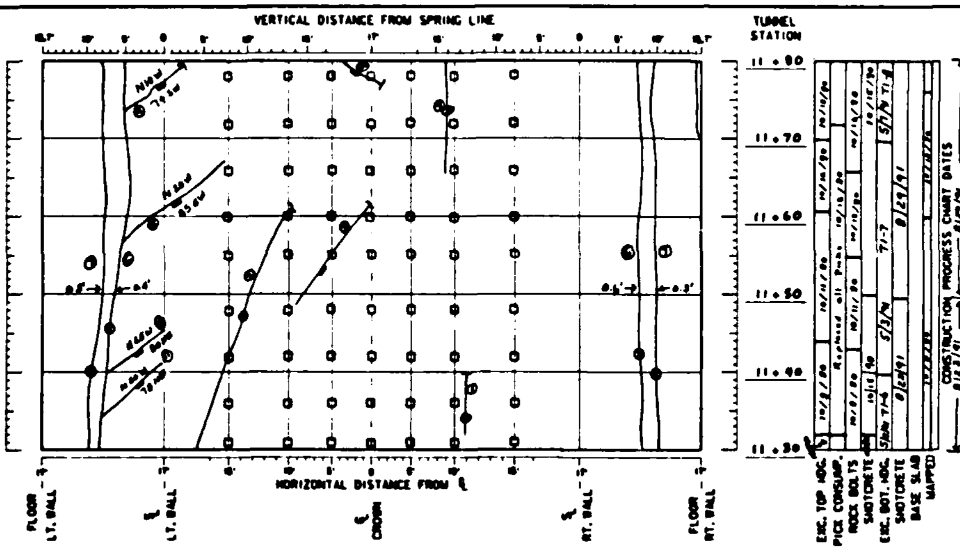
US Army Corps of Engineers

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 1

STATION 10+80 TO 11+30

SHEET 3 of 42



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T1-6 through T1-8

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd pln	Tim Sby	C4, O0, T2, HL9, R6, M2 [illegible] Nearly horizontal
2	Bdd pln		C4, O0, T2, HL9, R6, M2 Nearly horizontal
3	Jt		C3, O0, T2, HL9, R6, M2 N18W 85NE
4	Bdd pln		C3, O0, T2, HL9, R6, M2 Nearly horizontal
5	Jt		C3, O0, T2, HL9, R6, M2 N80E 85NW
6,7	C.gm. bd	Ts	Silt, near horizontal, [illegible], c.gm., H.gc., H4, M4, B3
8	Jt.	Ts	Joint, N30W, 85SW, SP2, C3, O0, T8, R3, HL9, M2
9	Jt.	Ts	Joint, N40W, 76 SW, SP2, C3, O0, T8, R3, HL4, M2
10	Jt.	Ts	Joint, N16W, [illegible]
11	Jt.	Ts	Joint, N20W, 78NE

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
10/10/90 Replaced all picks on Boatop?

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers

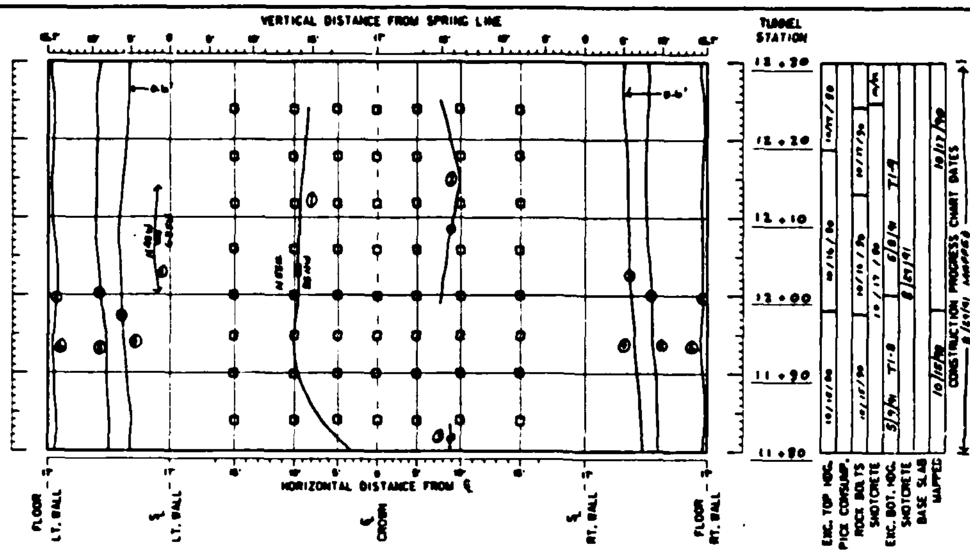
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 1

STATION 11+30 TO 11+80

SHEET 4 of 42

PLATE D-8



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T1-8 and T1-9.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	J1	Tim Sky	C3, 00, T5, H14, R5, M2 — WAVE BEND
2	J1		C4, 00, T5, H10, R5, M2 — Nearly horizontal
3	J1		C3, 00, T5, H10, R5, M2 — Nearly horizontal
4,5	Cgm bd	TS	Sist, near horizontal, planar, Cgm, lt gr, H4, W1, B3
6	Cgm bd	TS	Sist, near horizontal, planar, Cgm, lt gr, H4, W1, B4
7	Jt	Ts	Joint, N40W, 63SW, C3, 06, T6, R5, H14, M2

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

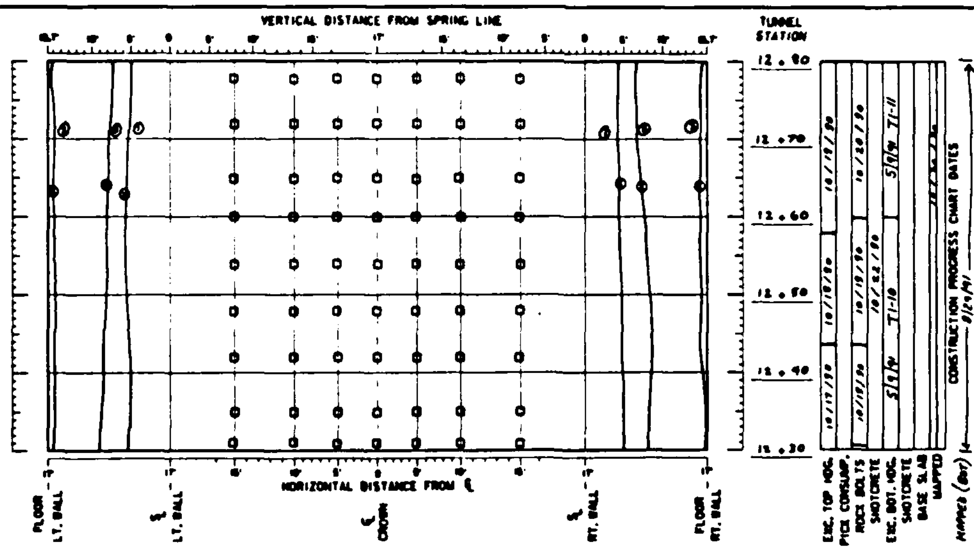
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 1

STATION 11+80 TO 12+30

SHEET 5 OF 42



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T1-10 and T1-11

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	Cgm bd	TS	Sist, near horizontal, planar, Cgm, lt gr, H4, W1, B3
3	Cgm bd	TS	Sist, near horizontal, planar, Cgm, lt gr, H4, W1, B4

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers

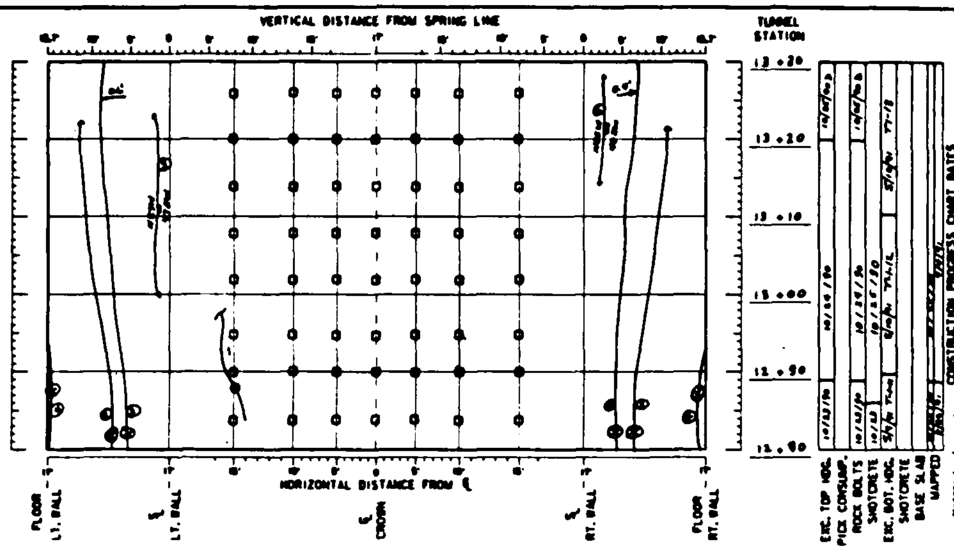
HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 1

STATION 12+30 TO 12+80

SHEET 6 OF 42

PLATE D-9



LEGEND

ROCK BOLT LOCATION	□
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T1-11 thru T1-13.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd Pln.	Tm Shy	C3, 01, T1, HL4, R3, M1 Nearly horizontal
2,3	Cgm beds	Tm Shy	Sst, cgm, lgr, H4, W2, R3 near horizontal, green
4	Cgm bed	Tm Shy	Sst, cgm, lgr, H4, W2, R4 near horizontal, green
5	Joint	Tm Shy	C1, 08, T8, HL4, R3, M2 N 27 W, 47 SW
6	Joint	Tm Shy	C3, 00, T8, HL4, R3, M2 N 25 W, 40 SW

REMARKS: Tunnel Alignment - N 43°24'45"W. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.

SCALE 1" = 10'

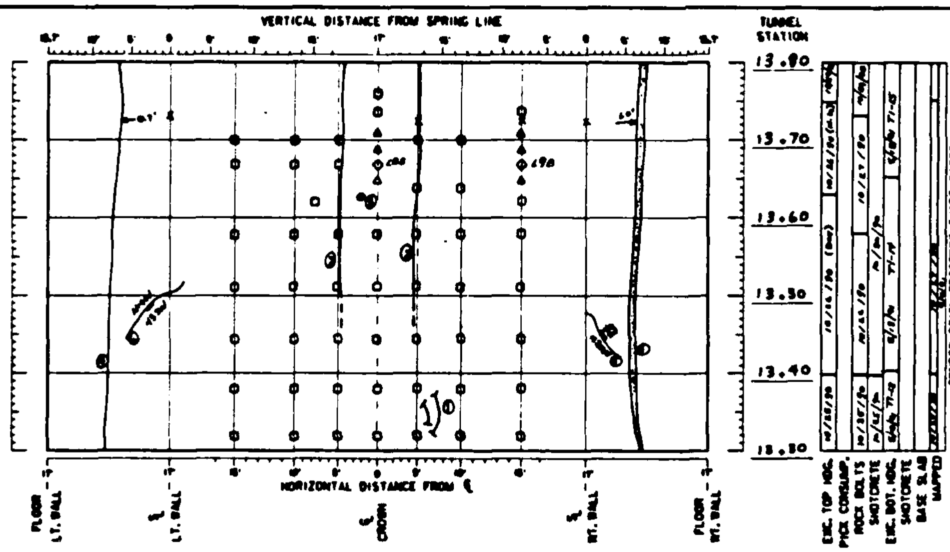
Geology By / Drawn By / Checked By / Date

US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 1

STATION 12+80 TO 13+30

SHEET 7 OF 42



LEGEND

ROCK BOLT LOCATION	□
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T1-13 thru T1-16.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Frac.	Tm Shy	C2, 00, T1, HL4, R2, M1 Pattern conjugate
2	Bdd pln	Bal Bow	00, T0, HL4, R6
3	MPBX	Bal Bow	MPBX @ location, head ... 57 ft above Tunnel grade
4	Cgm bed	Tm Shy	Sst, cgm, H4, W2, R3, near horizontal, lgr, green
5	Joint	Tm Shy	C3, 08, T8, R6, HL4, M2, N 30 W, 40 SW
6	Joint	Tm Shy	C3, 08, T8, R6, HL4, M2, N 40 W, 40 SW

REMARKS: Tunnel Alignment - N 43°24'45"W. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.
10/27/80 Array "B" installed
10' SPBX - 13+68
Load Cell - 13+67
6' SPBX - 13+69
1' SPBX - 13+71
TX - 13+72 ℄
Face @ Sta - 13+78

SCALE 1" = 10'

Geology By / Drawn By / Checked By / Date

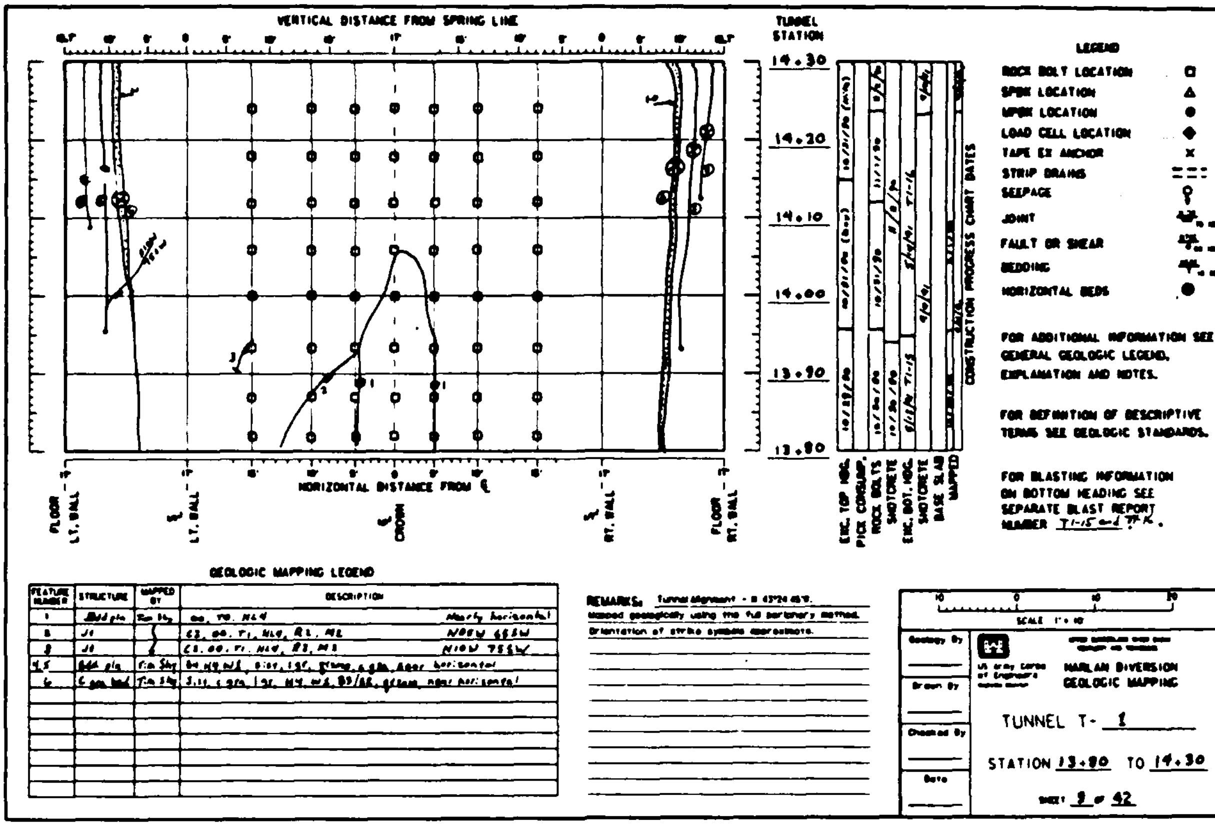
US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 1

STATION 13+30 TO 13+80

SHEET 8 OF 42

PLATE D-10


VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
14+30
14+20
14+10
14+00
13+90
13+80
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR RT. WALL
EXC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T1-15 and T1-16.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
SCALE 1" = 10'
Geology By
Drawn By
Checked By
Date
US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 1
STATION 13+80 TO 14+30
SHEET 9 OF 42

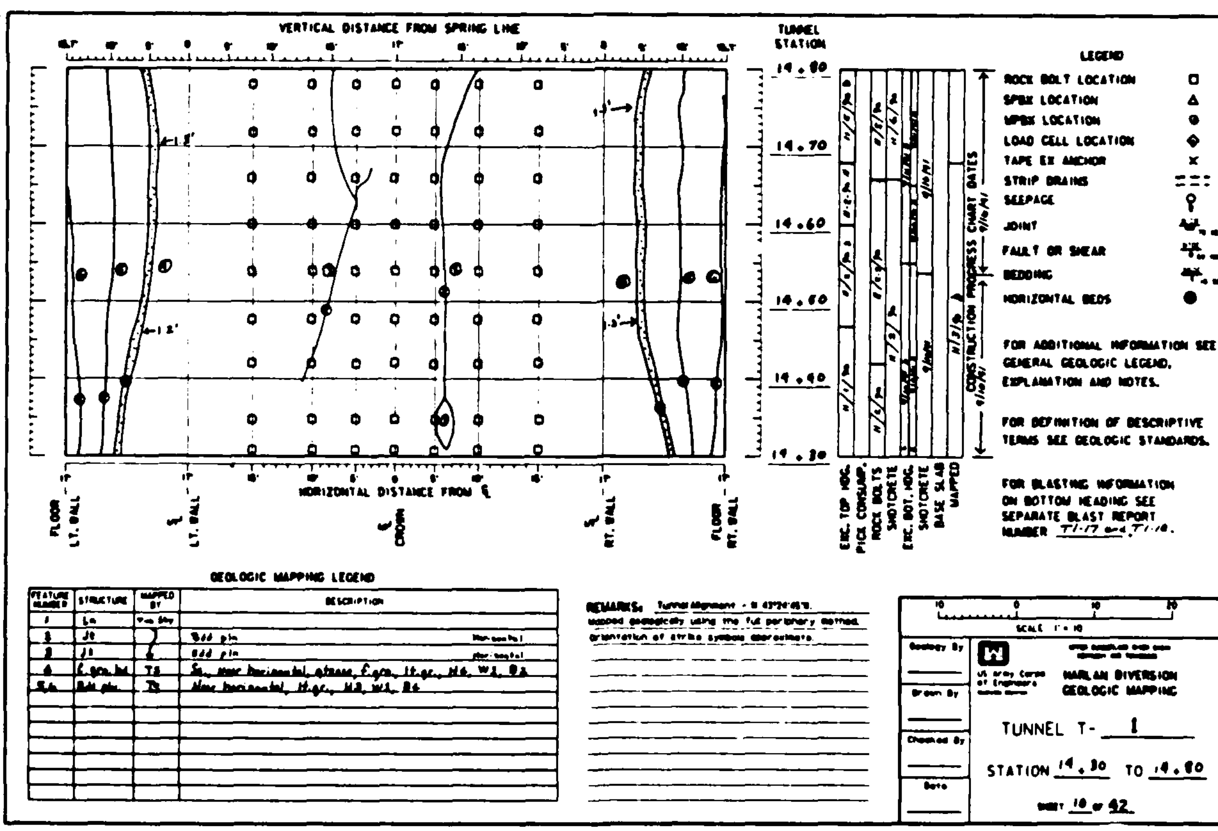
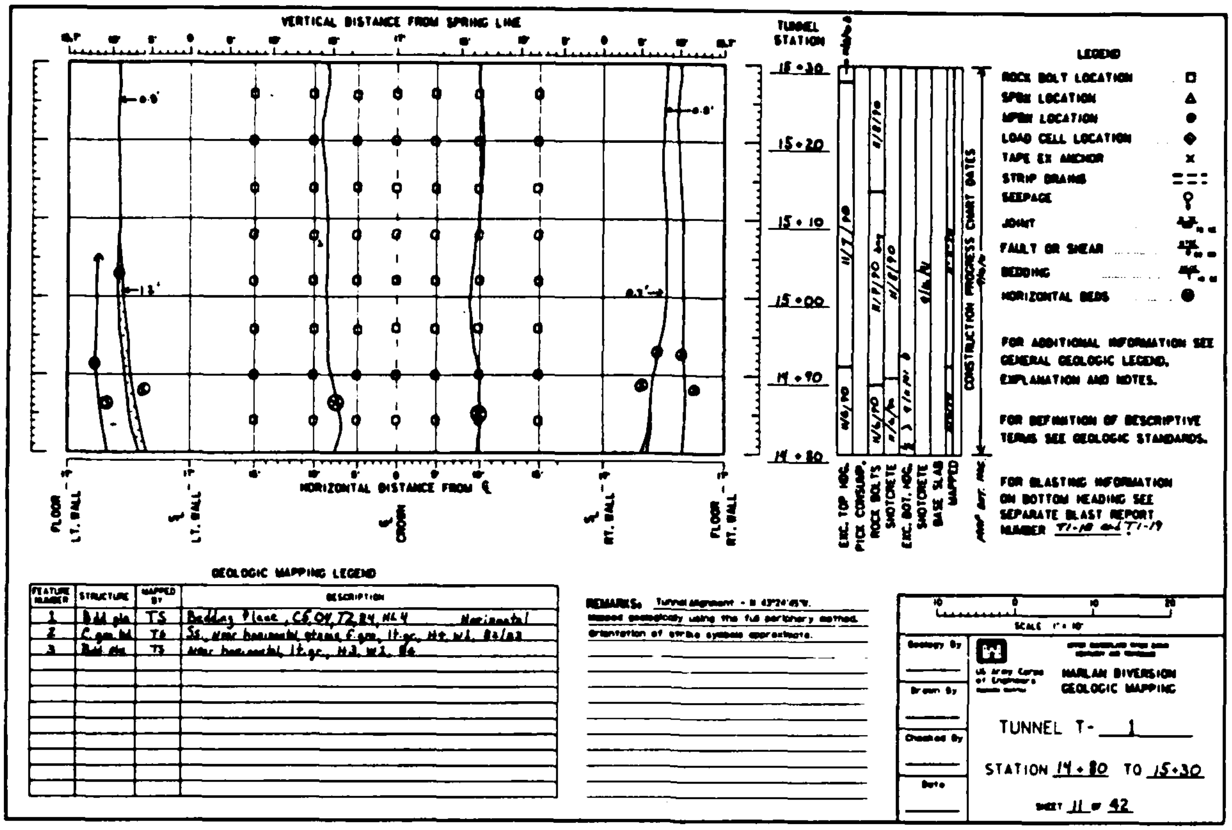
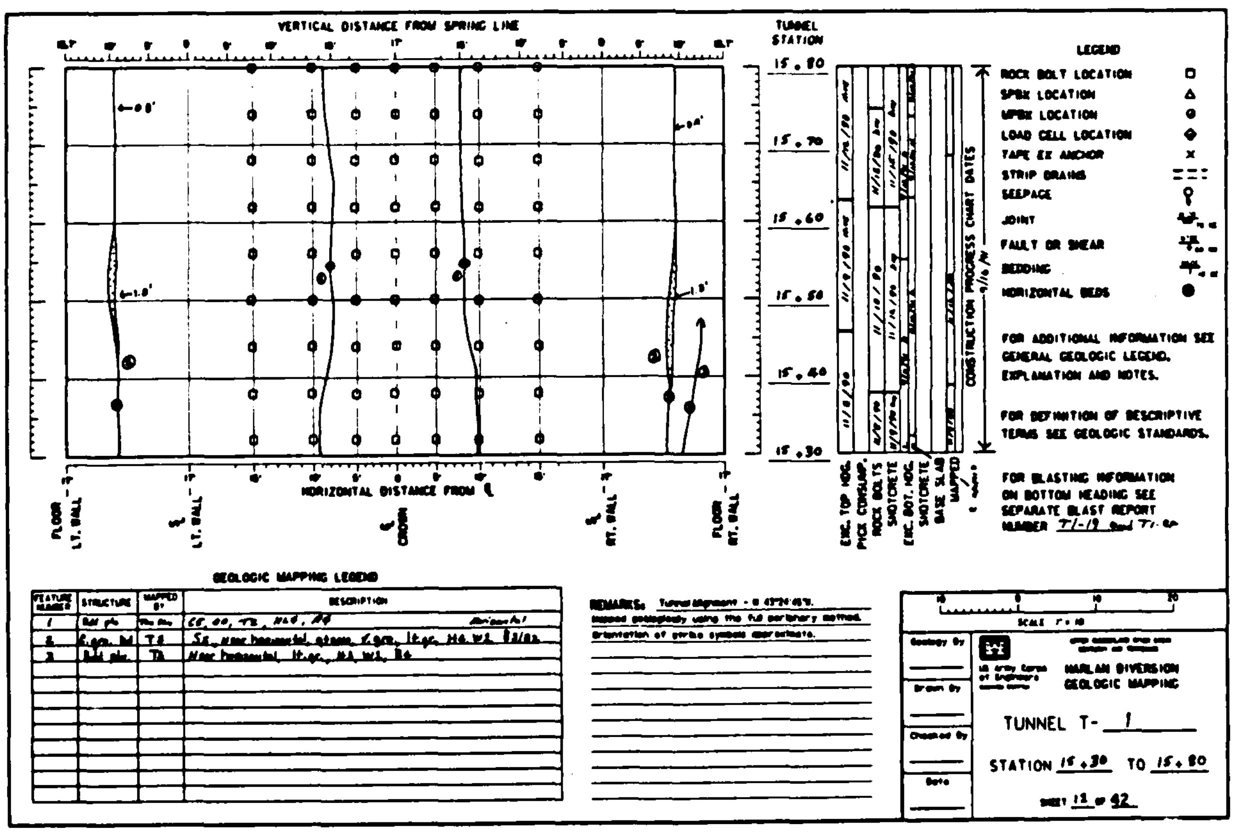

VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
14+80
14+70
14+60
14+50
14+40
14+30
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR RT. WALL
EXC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T1-17 and T1-18.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
SCALE 1" = 10'
Geology By
Drawn By
Checked By
Date
US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 1
STATION 14+30 TO 14+80
SHEET 10 OF 42

PLATE D-11

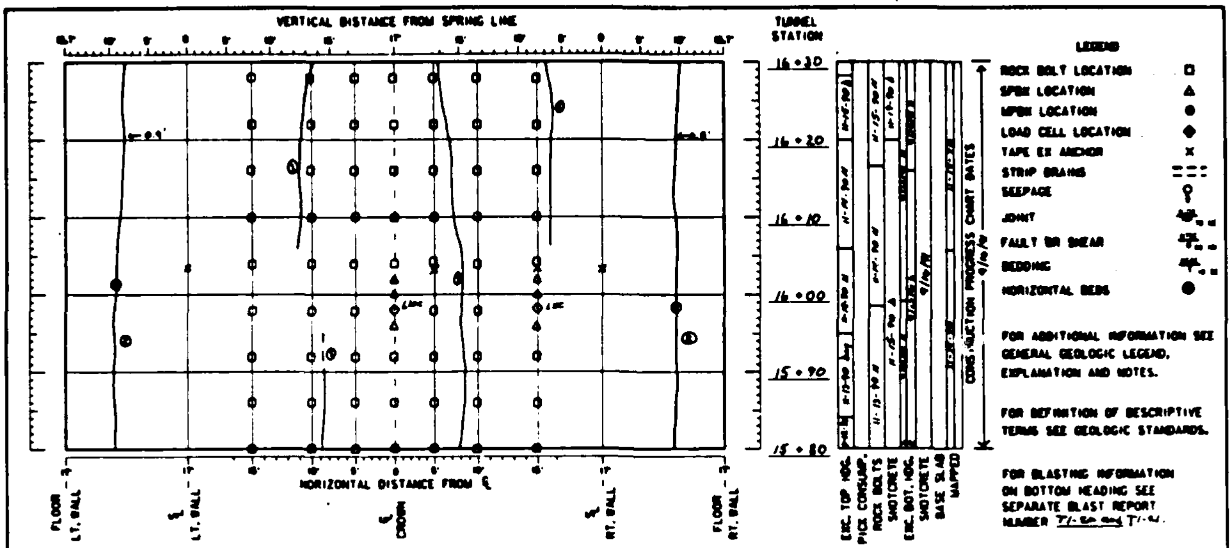


VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
15+30
15+20
15+10
15+00
14+90
14+80
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
℄ LT. WALL
℄ CROWN
℄ RT. WALL
FLOOR RT. WALL
EXC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T1-18 and T1-19
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
1 | Bdd pln | TS | Bedding Plane, CS, 04, T2, 84, HL4 Horizontal
2 | C.gm. bd | TS | Ss, near horizontal, ...
3 | Bdd pln | TS | Near horizontal, lt.gr., ...
REMARKS: Tunnel alignment - N 43°24'45"W. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.
SCALE 1" = 10'
Geology By
Drawn By
Checked By
Date
US Army Corps of Engineers
HARLAN DIVERSION GEOLOGIC MAPPING
TUNNEL T- 1
STATION 14+80 TO 15+30
SHEET 11 OF 42



VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
15+80
15+70
15+60
15+50
15+40
15+30
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
℄ LT. WALL
℄ CROWN
℄ RT. WALL
FLOOR RT. WALL
EXC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T1-19 and T1-20
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
1 | Bdd pln | ... | CS, 04, T2, H4, 84 Horizontal
2 | C.gm. bd | TS | Ss, near horizontal, ...
3 | Bdd pln. | TS | Near horizontal, lt.gr., ...
REMARKS: Tunnel alignment - N 43°24'45"W. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.
SCALE 1" = 10'
Geology By
Drawn By
Checked By
Date
US Army Corps of Engineers
HARLAN DIVERSION GEOLOGIC MAPPING
TUNNEL T- 1
STATION 15+30 TO 15+80
SHEET 12 OF 42

PLATE D-12



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd pln	Paul Roos	Bedding plane O Ø, T Ø, RS
			Array "C"
			Installed 11-14-90
			Face at 16+06
			O Load Cells 15+98
			Δ 5' SPBX's 16+00
			Δ 1' SPBX's 16+02
			x TXs 16+03.5
			Δ 10' SPBX's 15+96
2	C.gon bd.	TS	Ss, near horizontal, gt mas, f.gm, lt.gr, H4, W2, B2/B2

REMARKS: Tunnel alignment - N 43°24'45"E
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

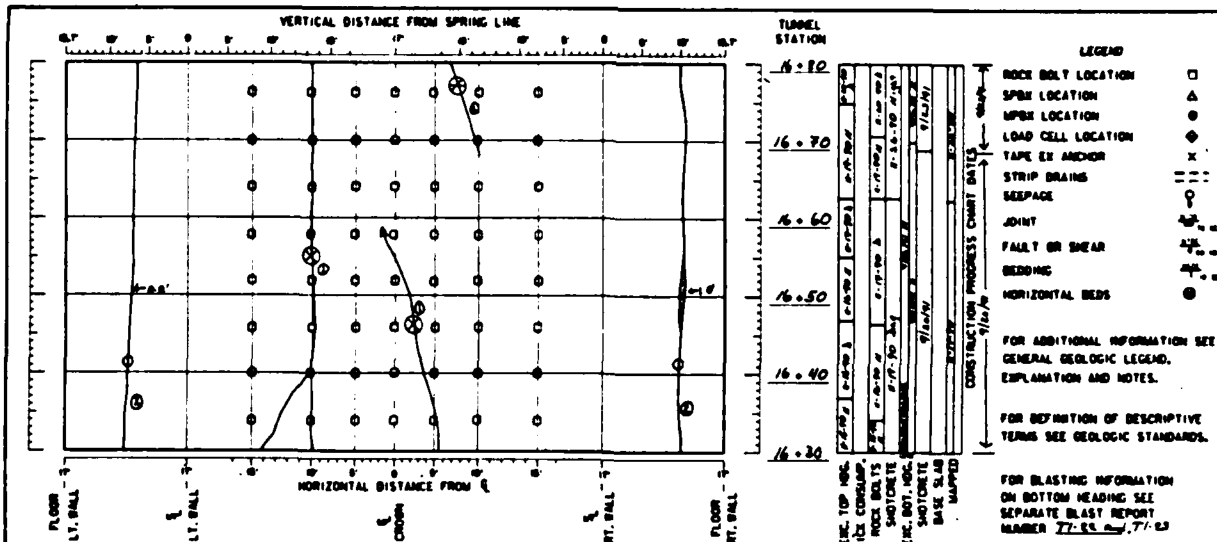
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 1

STATION 15+80 TO 16+30

SHEET 13 OF 42



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd pln	Tim Bly	T Ø, C9, O Ø, RS, HL4 Horizontal
2	C.gon bd.	TS	Ss, near horizontal, gt mas, f.gm, lt.gr, H4, W2, B2/B2

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
13+35 - Broken TX cover (ARRAY "B")
No cover on Load Cell group

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

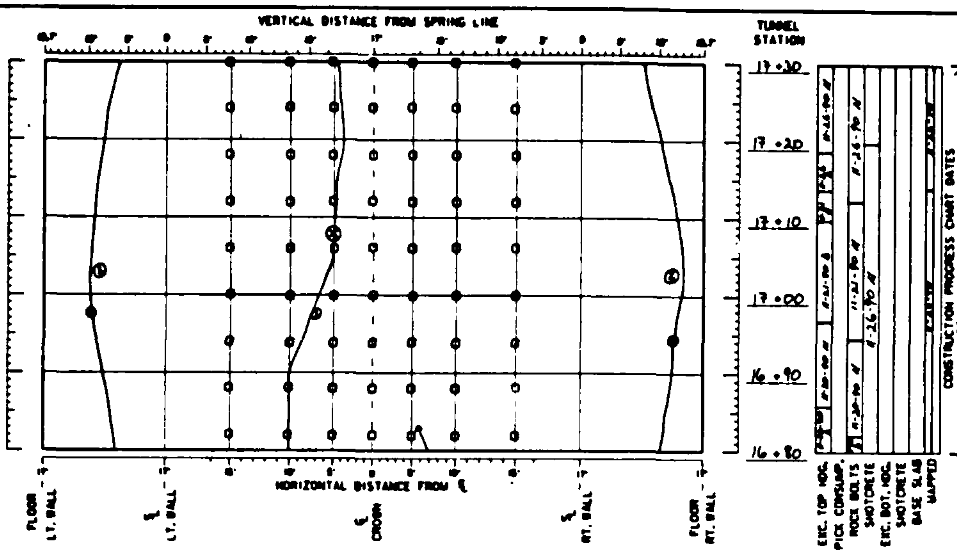
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 1

STATION 16+30 TO 16+80

SHEET 14 OF 42



LEGEND

- ROCK BOLT LOCATION □
- SPBX LOCATION △
- MPBX LOCATION ●
- LOAD CELL LOCATION ◆
- TAPE EX ANCHOR ×
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS ●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER 71-89 and 71-85

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd pln	T+Shy	OØ HL4 C3 M4 Horizontal
2	Cgm bd.	TS	Ss, near horizontal, gl[illegible], f.grn, lt gr, H4, w1, B3

REMARKS: Tunnel alignment - N 43°24'45"E
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

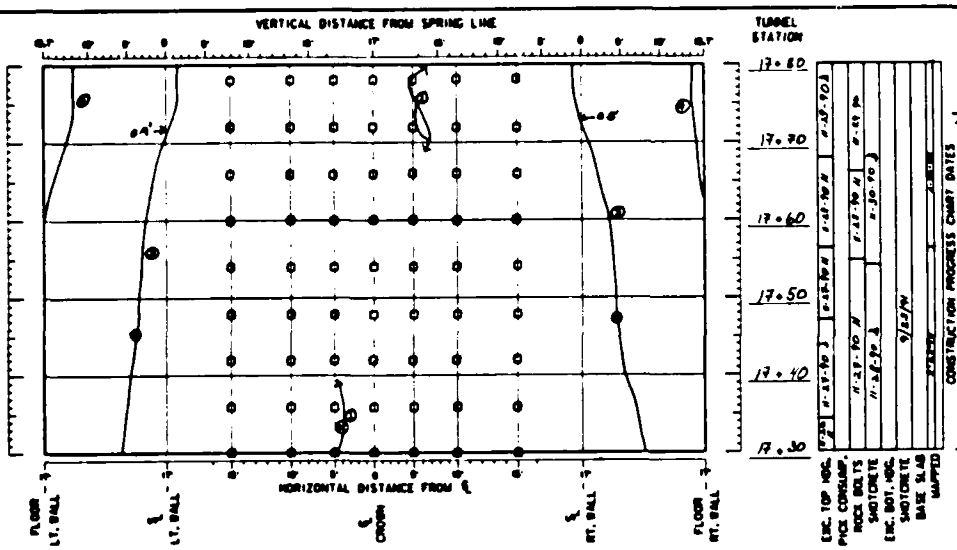
US Army Corps of Engineers

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 1

STATION 16+80 TO 17+30

SHEET 15 of 42



LEGEND

- ROCK BOLT LOCATION □
- SPBX LOCATION △
- MPBX LOCATION ●
- LOAD CELL LOCATION ◆
- TAPE EX ANCHOR ×
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS ●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER 71-95 and 71-86

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd pln	T+Shy	OØ HL4, C3 M4 Horizontal
2	Frac	T+Shy	OØ HL4, C2, M2 bonding is loose
3	Cgm bd	TS	Ss, near horizontal, gl[illegible], f.grn, lt.gr, H4, w1, B3/B2
4	Bdd pln	TS	lt.gr, H4, w1, B6

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

US Army Corps of Engineers

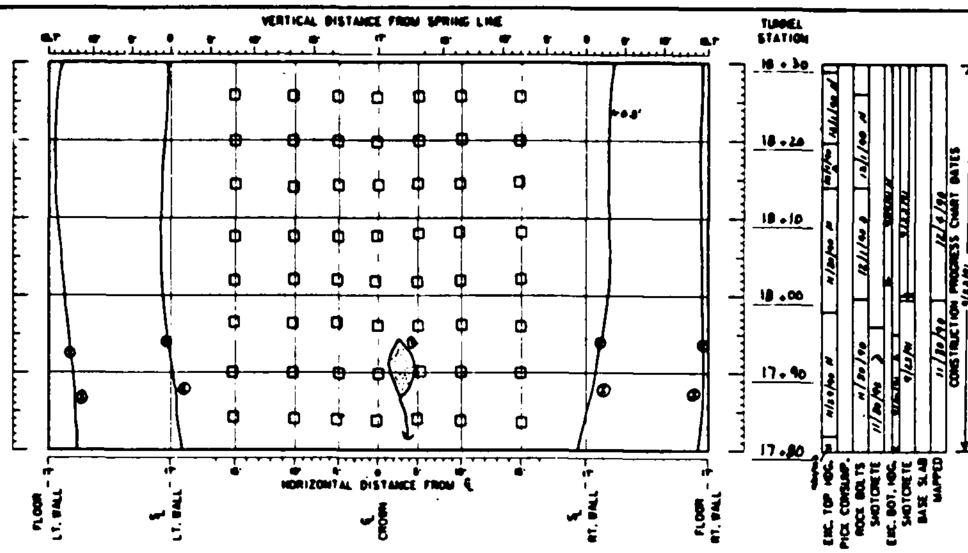
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 1

STATION 17+30 TO 17+80

SHEET 16 of 42

PLATE D-14



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ________.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	LENS	TS	Ss lens
2	Cgm bd	TS	Ss, near horizontal, glacial, Cgm, lt gc, H4, W1, B3
3	Bdd pln	TS	Ss, near horizontal, Cgm, lt gc, H4, W1, B4

REMARKS: Tunnel Alignment - N 43°24' 45"E. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.

SCALE 1" = 10

US Army Corps of Engineers

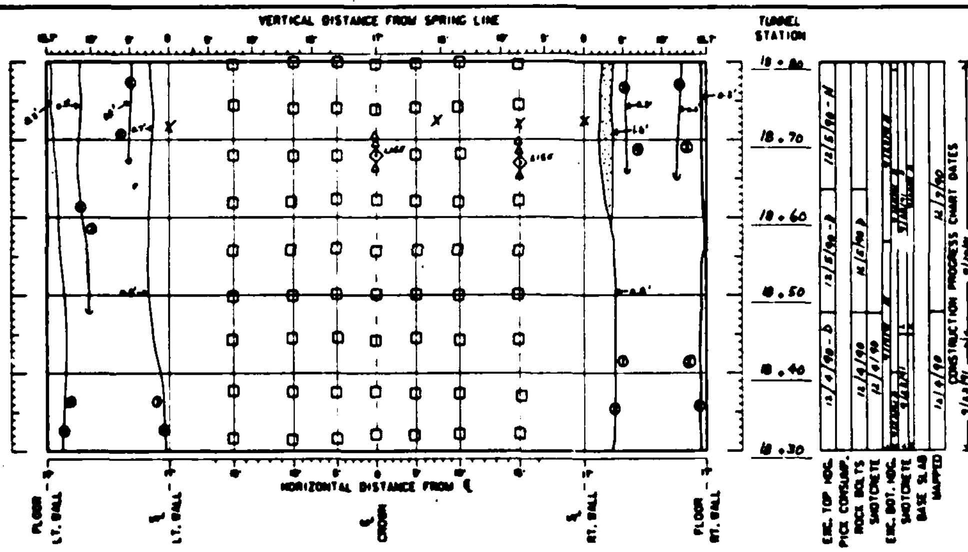
HARLAN DIVERSION GEOLOGIC MAPPING

Geology By / Drawn By / Checked By / Date

TUNNEL T- 2

STATION 17+80 TO 18+30

SHEET 17 OF 42



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ________.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Cgm bd	TS	Ss, near horizontal, glacial, Cgm, lt gc, H4, W1, B3
2	Bdd pln	TS	Ss, near horizontal, glacial, Cgm, lt gc, B4
3	Cgm bd	TS	Ss, near horizontal, glacial, Cgm, lt gc, H4, W1, B4
4	Cgm bd	TS	Ss, near horizontal, glacial, Cgm, lt gc, H4, W1, B3

REMARKS: Tunnel Alignment - N 43°24' 45"E. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.
ARRAY "B" 18+63, INSTALLED 12/6/90

Ss lens exposed at spring line 18+58 → 18+64

SCALE 1" = 10

US Army Corps of Engineers

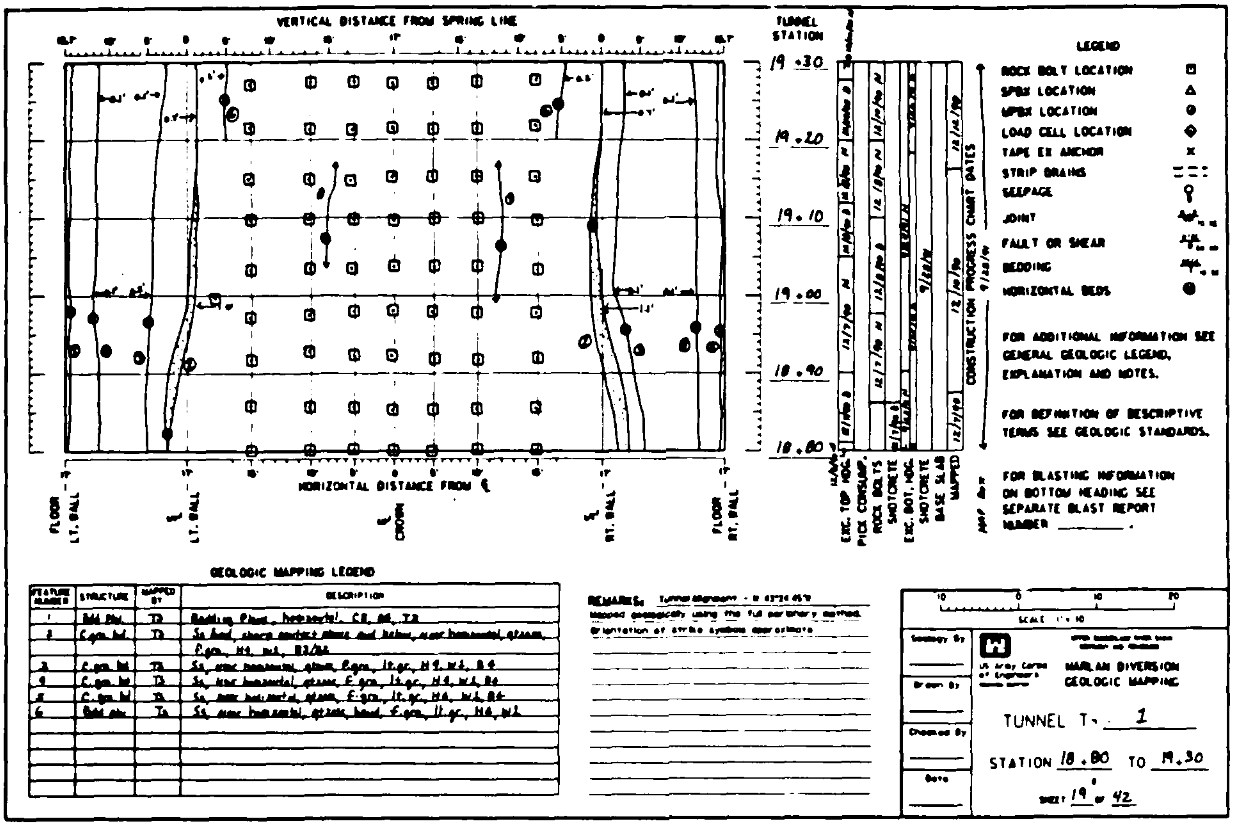
HARLAN DIVERSION GEOLOGIC MAPPING

Geology By / Drawn By / Checked By / Date

TUNNEL T- 2

STATION 18+30 TO 18+80

SHEET 18 OF 42


VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
19+30
19+20
19+10
19+00
18+90
18+80
HORIZONTAL DISTANCE FROM ℄
FLOOR - LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR - RT. WALL
EXC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
SCALE
US Army Corps of Engineers
HARLAN DIVERSION GEOLOGIC MAPPING
TUNNEL T- 1
STATION 18+80 TO 19+30
SHEET 19 OF 42

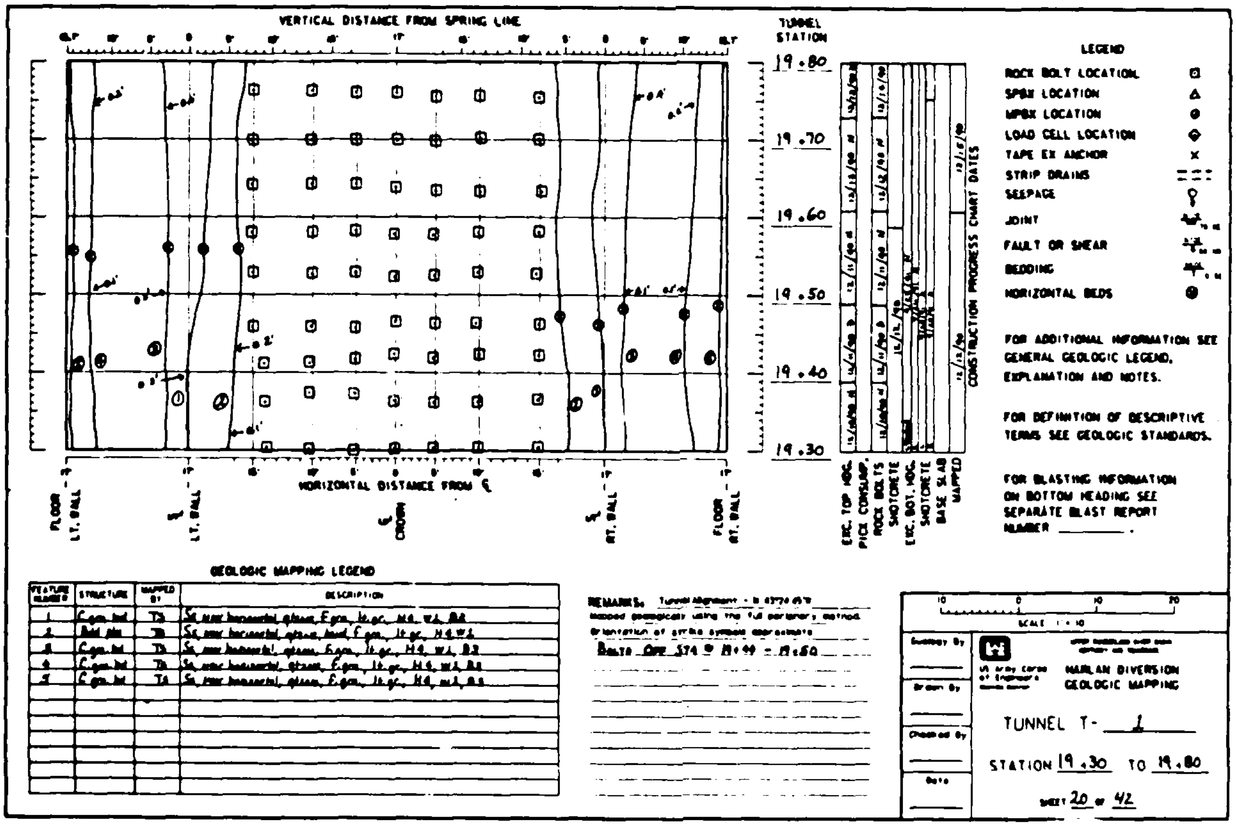
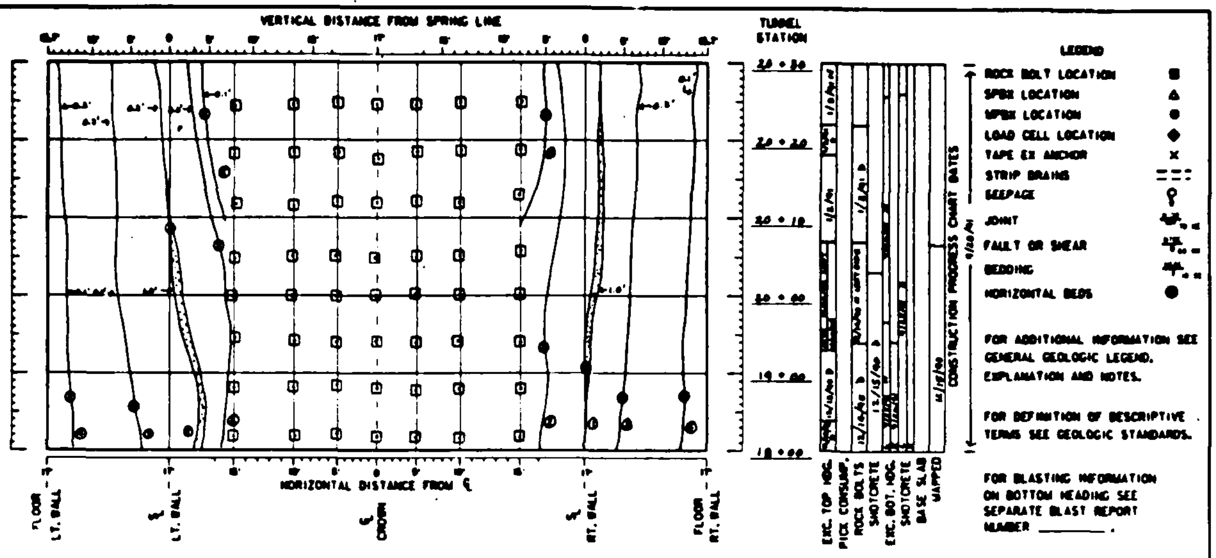

VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
19+80
19+70
19+60
19+50
19+40
19+30
HORIZONTAL DISTANCE FROM ℄
FLOOR - LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR - RT. WALL
EXC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
SCALE
US Army Corps of Engineers
HARLAN DIVERSION GEOLOGIC MAPPING
TUNNEL T- 1
STATION 19+30 TO 19+80
SHEET 20 OF 42

PLATE D-16



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Ss Bed	TS	Ss bd, near horizontal, lt gr, H4, W1, B3
2	Ss Bed	TS	Ss bd, near horizontal, lt gr, H4, W1, B3
3	Ss Bed	TS	Ss bd, near horizontal, lt gr, f gm, H4, W1, B3
4	Ss Bed	TS	Ss bd, near horizontal, lt gr, f gm, H4, W1, B3
5	Ss Bed	TS	Ss bd, near horizontal, lt gr, f gm, H4, W1, B3

REMARKS. Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
* Power? n/a 12/14/90 -
1 Bolts at 20+00 and 20+06 installed on left side only (12/14/90) due to power breakdown.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

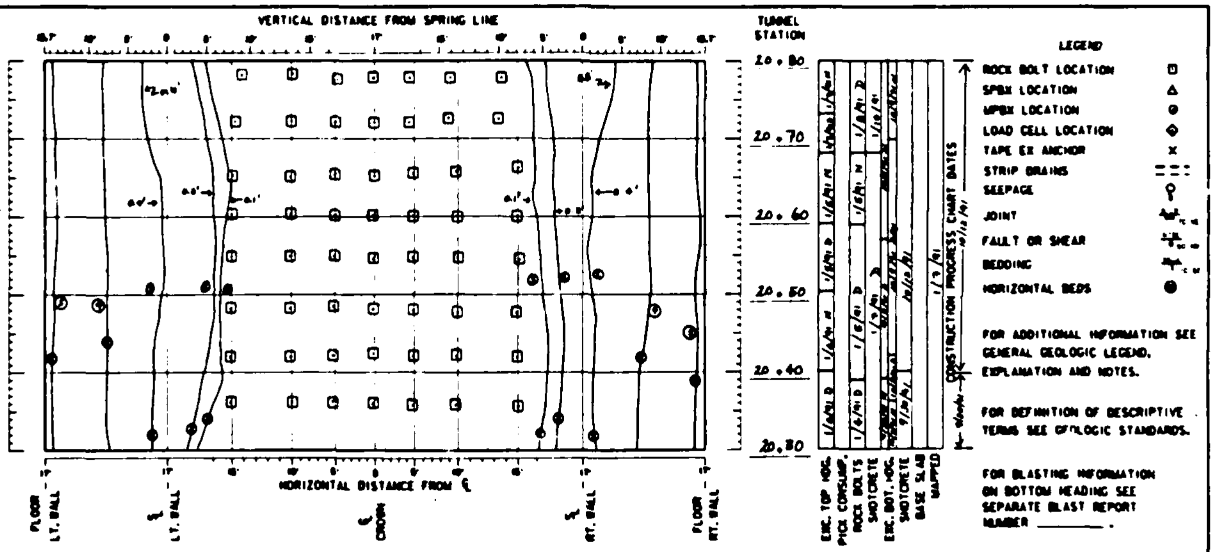
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 1

STATION 19 + 80 TO 20 + 30

SHEET 21 OF 42



GEOLOGIC MAPPING LEGEND

all near horizontal

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Ss Bed	TS	0.4' thk, H4, W1, B4, qtzose, lt gr, sh bands, conch frac.
2	Ss Bed	TS	0.2' thk, H4, W1, B4, qtzose, lt gr, sh bands, conch frac.
3	Ss Bed	TS	0.1' thk, H4, W1, B4, qtzose, lt gr, sh bands, conch frac.
4,5	Ss Bed	TS	Ss near horizontal, lt gr, v f gm, qtzose, H4, W1, B4

REMARKS. Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers

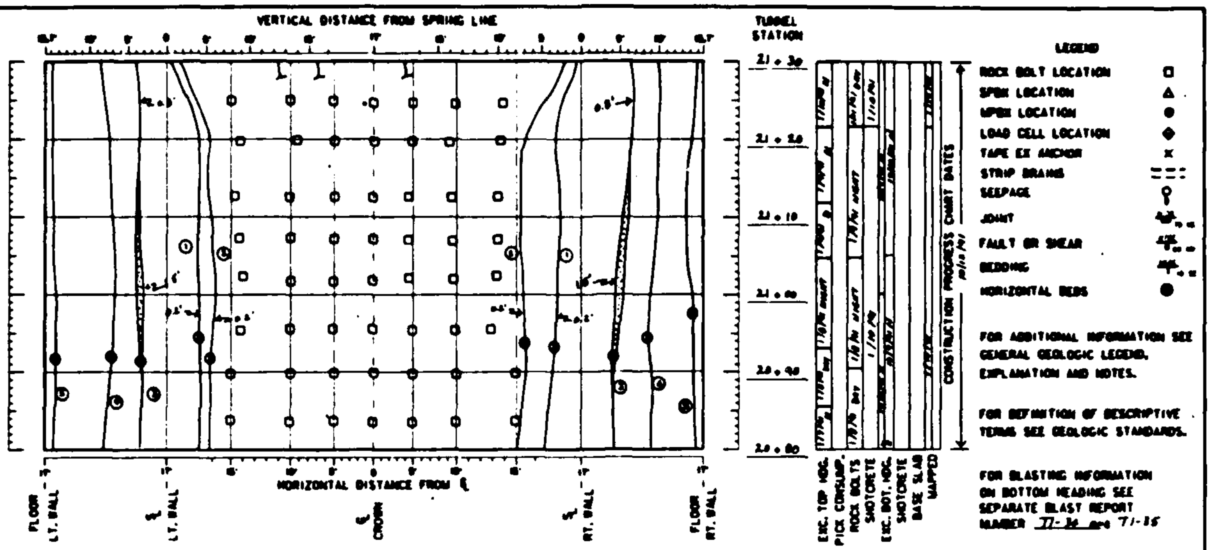
HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 1

STATION 20 + 30 TO 20 + 80

SHEET 22 OF 42

PLATE D-17



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1, 2	So Bdd	T. SHY	So, near horizontal, lt. gr., f. gm., qtzose, H4, W1, B3/B2.
3	So Bdd	T. SHY	So, near horizontal, lt. gr., v.f. gm., qtzose, H4, W1, B2.
4, 5	So Bdd	T. SHY	So, near horizontal, lt. gr., v.f. gm., qtzose, H4, W1, B4.

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full peripheral method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

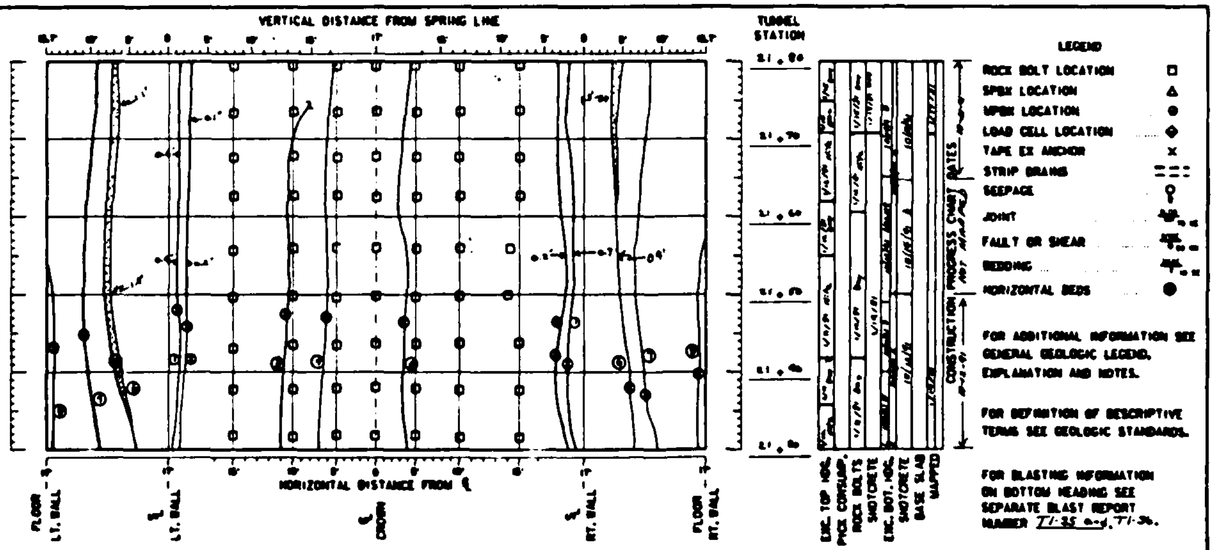
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 1

STATION 21 + 30 TO 20 + 80

SHEET 23 OF 42



GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1, 2, 3	Sh bed	T. SHY	lt gr., f. gm., cld., mas., no parting, conchoidal frac., horizontal
4, 5	Sdd Sh	T. SHY	Horizontal
6	So Bdd	T. SHY	So, near horizontal, lt gr., v.f. gm., qtzose, H4, W1, B1
7, 8	So Bdd	T. SHY	So, near horizontal, lt gr., v.f. gm., qtzose, H4, W1, B4

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full peripheral method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

US Army Corps of Engineers

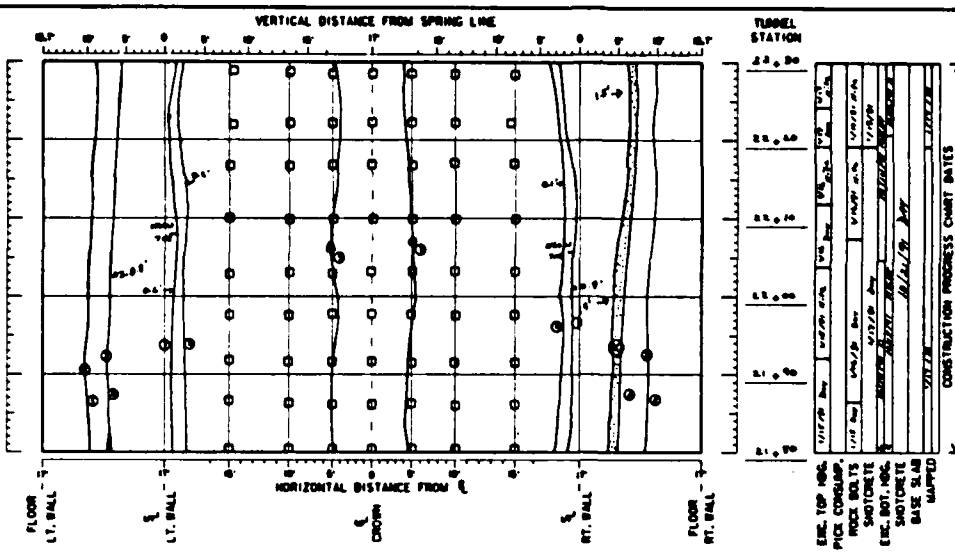
HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 1

STATION 21 + 30 TO 21 + 90

SHEET 24 OF 42

PLATE D-18



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T1-36 and T1-37.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1, 3	Ss bdd	[illegible]	[illegible]
2	bdd pln	[illegible]	horizontal
4	Ss Bdd	[illegible]	Ss, near horizontal, lt gr, v.f.gm, [illegible]
5	Ss Bdd	[illegible]	Ss, near horizontal, lt gr, v.f.gm, [illegible]

REMARKS: Tunnel alignment - [illegible]
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

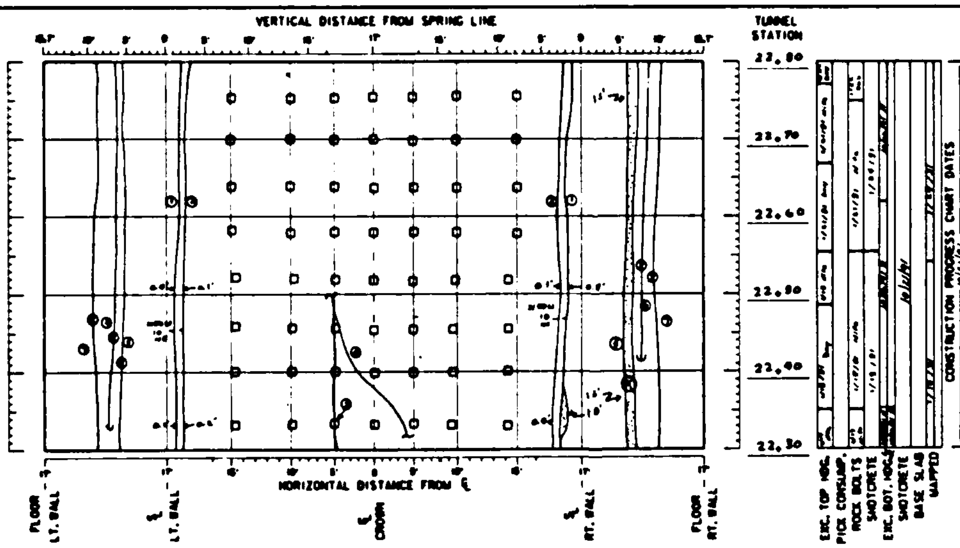
US Army Corps of Engineers

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 1

STATION 21+70 TO 21+80

SHEET 25 of 42



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T1-37 and T1-38

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1, 3	Ss bdd	[illegible]	[illegible]
2	[illegible]	[illegible]	See remarks
4	[illegible]	[illegible]	[illegible]
5	Ss Bdd	[illegible]	Ss, near horizontal, lt gr, v.f.gm, [illegible] 82/83
6, 7	Ss Bdd	[illegible]	Ss, near horizontal, lt gr, v.f.gm, [illegible] 84

REMARKS: Tunnel alignment - [illegible]
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
2 [illegible]

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

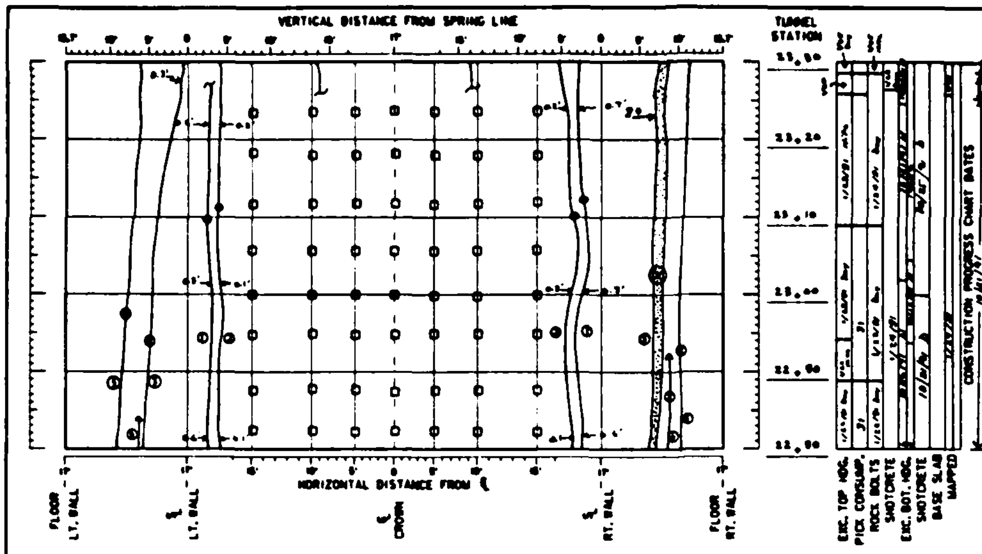
US Army Corps of Engineers

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 1

STATION 22+30 TO 22+80

SHEET 26 of 42



LEGEND

ROCK BOLT LOCATION	□
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T1-38 and T1-39.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1, 8	[illegible]	[illegible]	Ss, horizontal, lt. gr., [illegible], sh. bands, H5
7	Ss Bdd.	[illegible]	Ss, near horizontal, lt. gr., v.f. grn., H6, W1, B3/B4
4, 6	Ss Bdd.	[illegible]	Ss, near horizontal, lt. gr., v.f. grn., H6, W1, B4

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'
10 0 10 20

Geology By
Drawn By
Checked By
Date

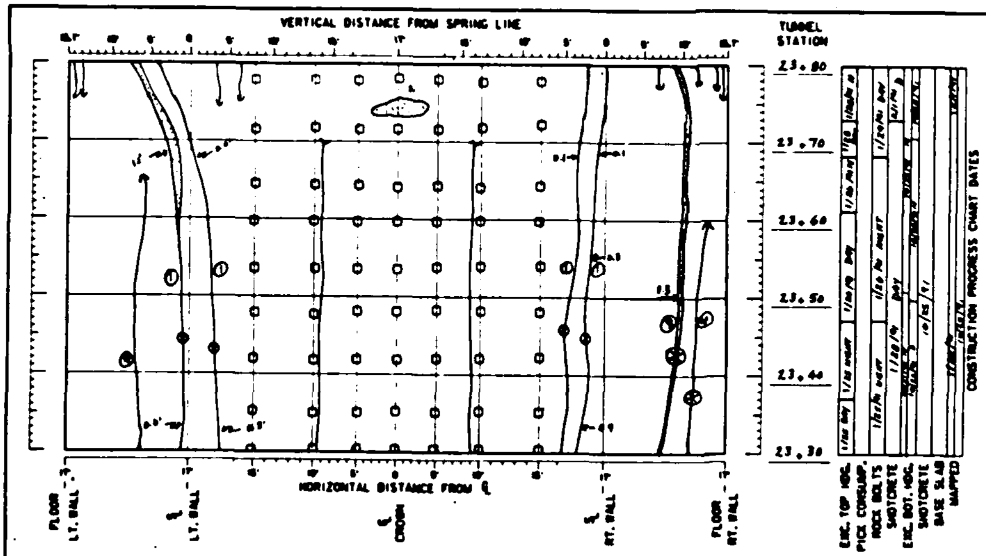
US Army Corps of Engineers

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 1

STATION 23+90 TO 23+90

SHEET 37 of 42



LEGEND

ROCK BOLT LOCATION	□
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T1-39 and T1-40

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Ss Bdd.	T [illegible]	Horizontal, lt. gr., [illegible], B3/B4
2	Ss [illegible]	T [illegible]	[illegible] lt. gr., uniform grn. size.
3	Ss bed	[illegible]	Ss v.f. grn, lgr, H6, W1, B3/B2, near horizontal, [illegible]
4	Ss bed	[illegible]	Ss, v.f. grn, lgr, H7, W1, B4, near horizontal, [illegible]

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
1/28/91 [illegible] [illegible] due to crushed [illegible].
[illegible] due to [illegible].
1/31/91 [illegible] 23+72, 23+78 [illegible] [illegible] (See Sheet).

SCALE 1" = 10'
10 0 10 20

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers

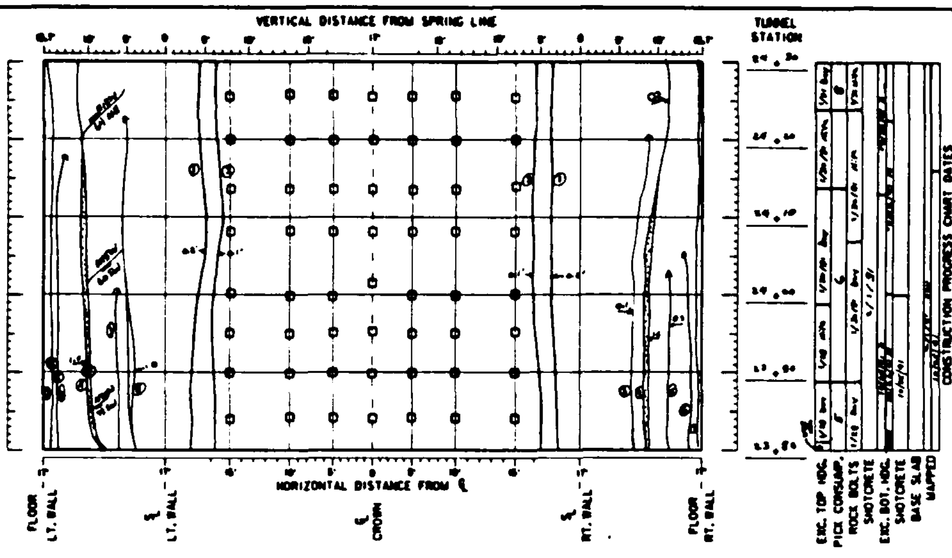
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 1

STATION 23+30 TO 23+80

SHEET 38 of 42

PLATE D-20



LEGEND

ROCK BOLT LOCATION □
SPBX LOCATION △
MPBX LOCATION ●
LOAD CELL LOCATION ◆
TAPE EX ANCHOR ×
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS ●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T1-40 and T1-41.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1, 6	Ss bdd	Tm Sy	B3 lt gr, th ...
2	Bdg Pln	...	Bdg pln near horizontal, lt gr.
4	SS bed	MG	SS near horizontal, lt gr, v fgm, H3, W1, B2
5, 6, 7	Bdg Pln	MG	Bdg pln, near horizontal, lt gr, B4
8	SS bed	MG	SS, near horizontal, l gr, v f gm, B3
	Joint	MG	Jt, N15W 60 SW, OP, TE, RS, HL4, M1
	Joint	MG	Jt, N20W, 73 SW, OP, TE, RS, HL4, M1

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
1/24/81 Bolts replaced 53+84. Original installation not at spec. bolts too short

SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

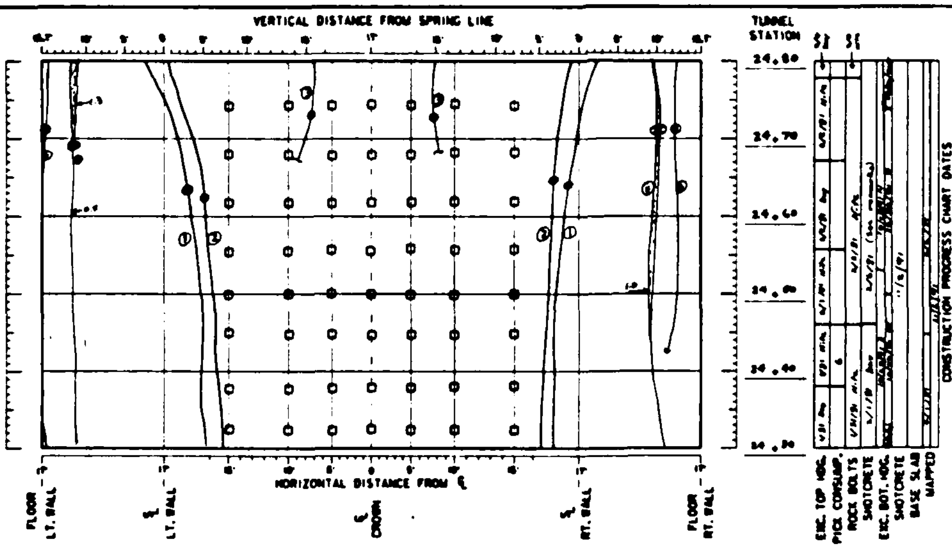
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 1

STATION 53+70 TO 54+30

SHEET 29 OF 42



LEGEND

ROCK BOLT LOCATION □
SPBX LOCATION △
MPBX LOCATION ●
LOAD CELL LOCATION ◆
TAPE EX ANCHOR ×
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS ●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T1-42 and T1-43.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1, 2	Ss bdd	...	lt gr, v bd, ... B3/B4 horizontal
3	bdd pln	...	B5 horizontal
4	Ss bed	Ta Sy	SS bed, v f gm, l gr, H4, W1, B3/B2, glauc, near horizontal
5	ss bed	Ta Sy	Ss bed, v f gm, l gr, H4, W1, B4, glauc, near horizontal.

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
8/6/81 ... rock bolts ... job ... completed

SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

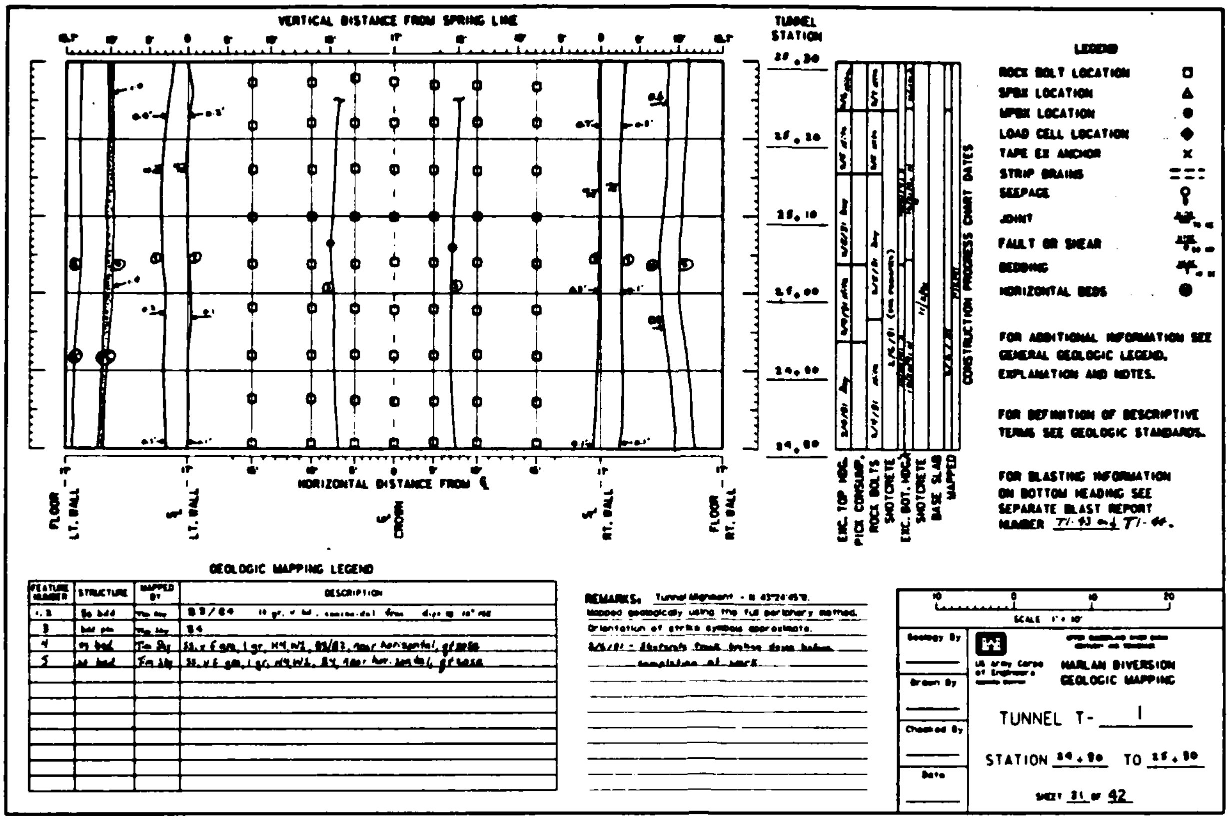
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 1

STATION 54+30 TO 54+90

SHEET 30 OF 42


VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR RT. WALL
EXC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T/-43 and T/-44.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS: Tunnel Alignment
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
SCALE
Geology By
Drawn By
Checked By
Date
US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 1
STATION 24+80 TO 25+30
SHEET 31 of 42

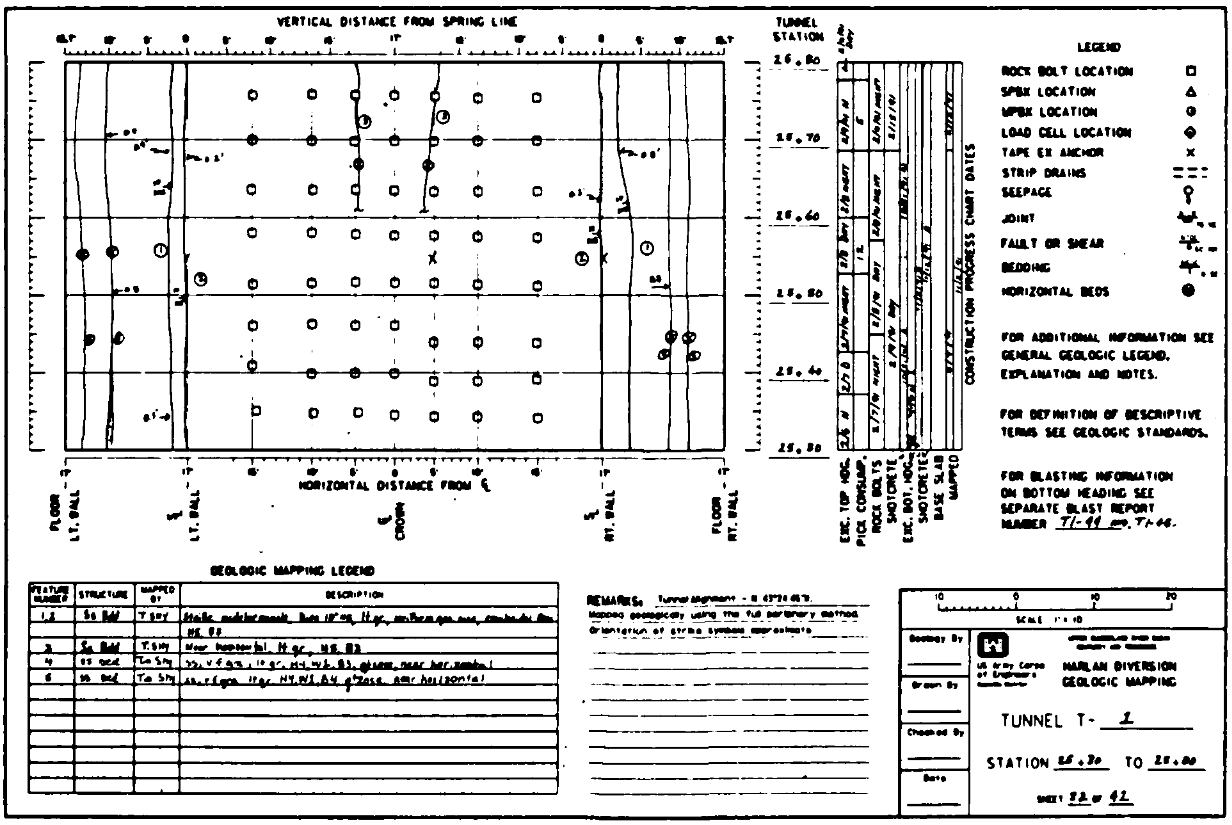
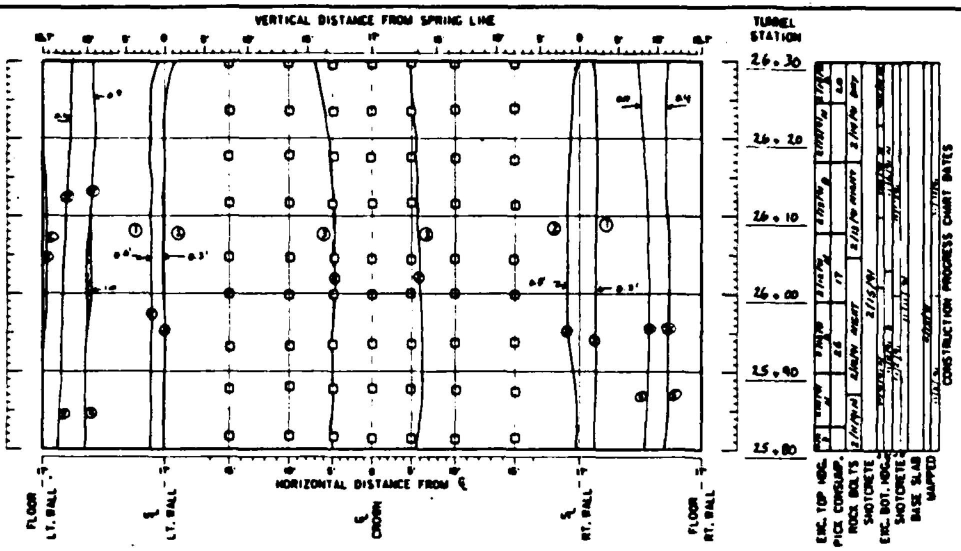

VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR RT. WALL
EXC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T/-44 and T/-46.
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS: Tunnel Alignment
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
SCALE
Geology By
Drawn By
Checked By
Date
US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 1
STATION 25+30 TO 25+80
SHEET 32 of 42

PLATE D-22



LEGEND

ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER 77-45 and 77-46

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	Bdd pln	T Sny	Ss near horizontal, qtzose, lt.gr., [illegible] HS, B3
3	Bdd pln	T Sny	Near horizontal, B4
4,5	Ss bed	Tin Sny	Ss, B3, H4, W2, l.gr., v.f.grn, qtzose, near horizontal

REMARKS: Tunnel Alignment - N 43°24'45"W. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

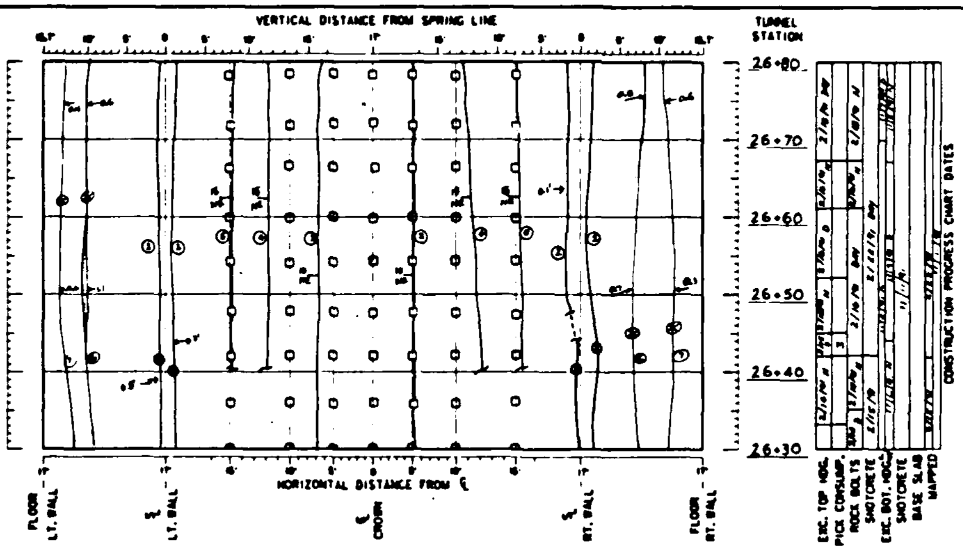
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 1

STATION 25+80 TO 26+30

SHEET 33 of 42



LEGEND

ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER 77-46 and 77-47

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	Bdd pln	T Sny	Ss, near horizontal, lt.gr., HS, B3
3	Bdd pln	T Sny	B4, Dips 10°NE
4,5	Bdd pln	[illegible]	Ss, Dips 15°NE, lt.gr., B4 [illegible]
6,7	Ss bed	Tin Sny	Ss, l.gr., v.f.grn, [illegible], H4, W2, qtzose, nr horizontal

REMARKS: Tunnel Alignment - N 43°24'45"W. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers

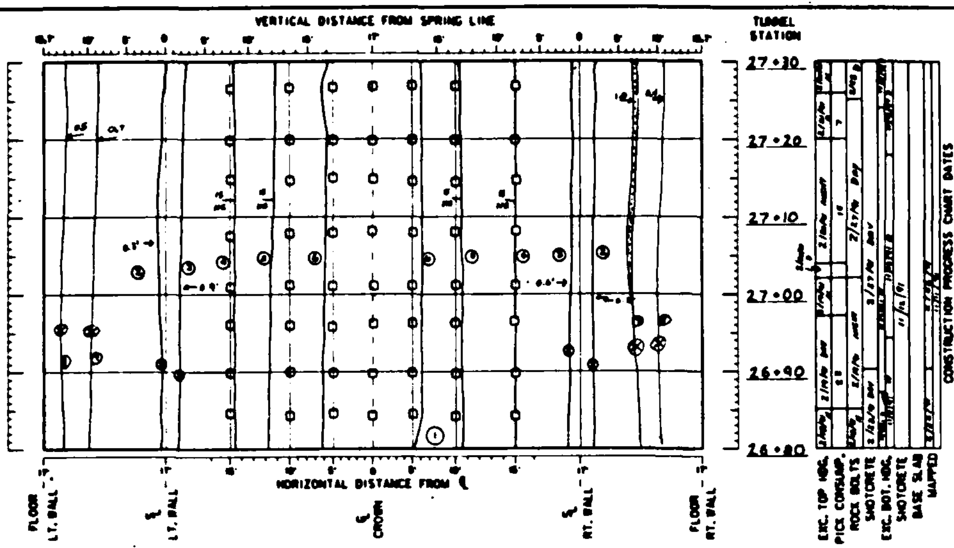
HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 1

STATION 26+30 TO 26+80

SHEET 34 of 42

PLATE D-23



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T1-47 and T1-48

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Conc. Hose	T. Sny	Dripping 4
2,3	Bdd pln	[illegible]	Ss, near horizontal, lt. gr., f.grn., H6, B3/B4
4,5	Bdd pln	[illegible]	Ss, Dipping 15° [illegible], lt. gr., f.grn., B4 pty
6	Bdd pln	[illegible]	B4
7	Ss bed	Tim Sny	Ss, v f.grn., l gr., H4, W2, B3, near horizontal, glzase
8	Ss bed	Tim Sny	Ss, v f.grn., l gr., H4, W2, B3, near horizontal, glzase

REMARKS: Tunnel alignment - N 43°24'45"E. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.

SCALE 1" = 10' (10 0 10 20)

Geology By
Drawn By
Checked By
Date

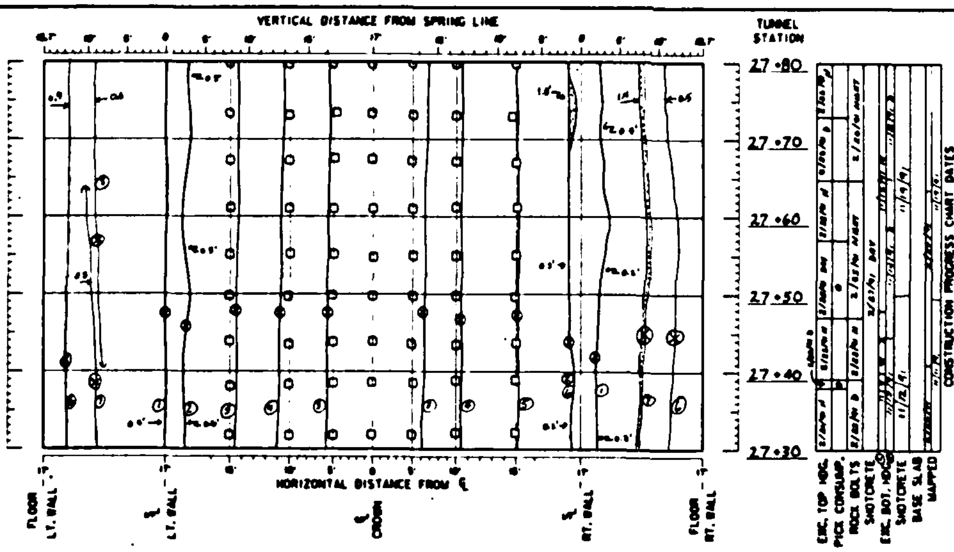
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 1

STATION 26+80 TO 27+30

SHEET 35 OF 42



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T1-48 and T1-49

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	Ss Bdd	[illegible]	Near horizontal, lt. gr., f.grn., H6, B2/B4
3	Bdd pln	[illegible]	Near horizontal, B4
4,5	Bdd pln	[illegible]	Ss, near horizontal, lt. gr., B4 pty
6,7	Ss beds	Tim Sny	Ss, v f.grn., l gr., H4, W2, B3/B2, near horizontal, glzase
8	Ss bed	Tim Sny	Ss, v f.grn., l gr., H4, W2, B3, near horizontal, glzase

REMARKS: Tunnel alignment - N 43°24'45"E. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.

SCALE 1" = 10' (10 0 10 20)

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers

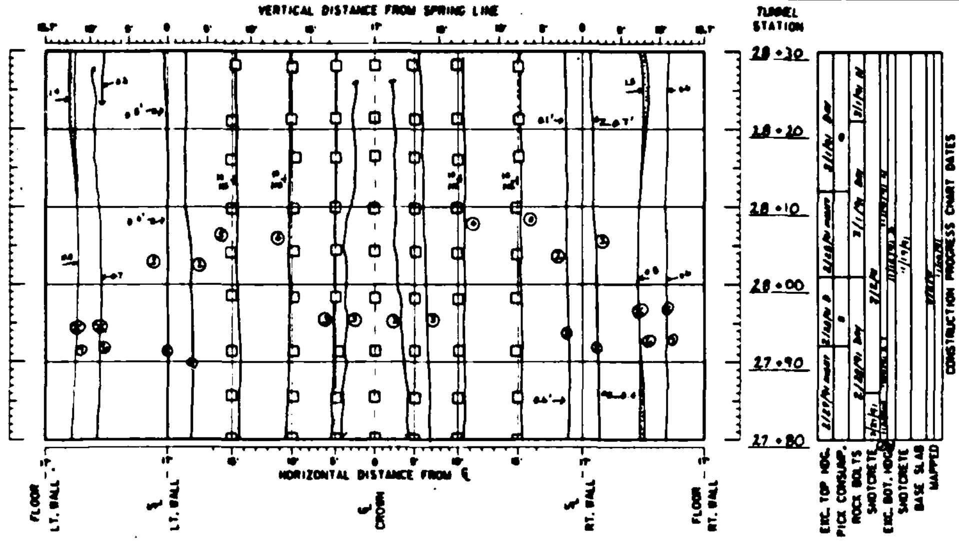
HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 1

STATION 27+30 TO 27+80

SHEET 36 OF 42

PLATE D-24



LEGEND

ROCK BOLT LOCATION □
SPBX LOCATION △
MPBX LOCATION ●
LOAD CELL LOCATION ◆
TAPE EX ANCHOR ×
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS ●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T1-49 and T1-50

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	Ss bdd	R. Baum	Near horizontal, lt.gr., f.grn., HS, B3/B4
3	bdds	R. Baum	B4
4,5	bdd pln.	R. Baum	Ss, bn - wnE, lt.gr., HS, B4 pty.
6,7	ss beds	Ta Shy	SS, vf grn, lgr, HH w/1, B3/B2, near horizontal, glossy

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
2/28/91 1430 hrs. Breakdown of Tamrock occurred after installation of one bolt @ Sta. 27+86

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

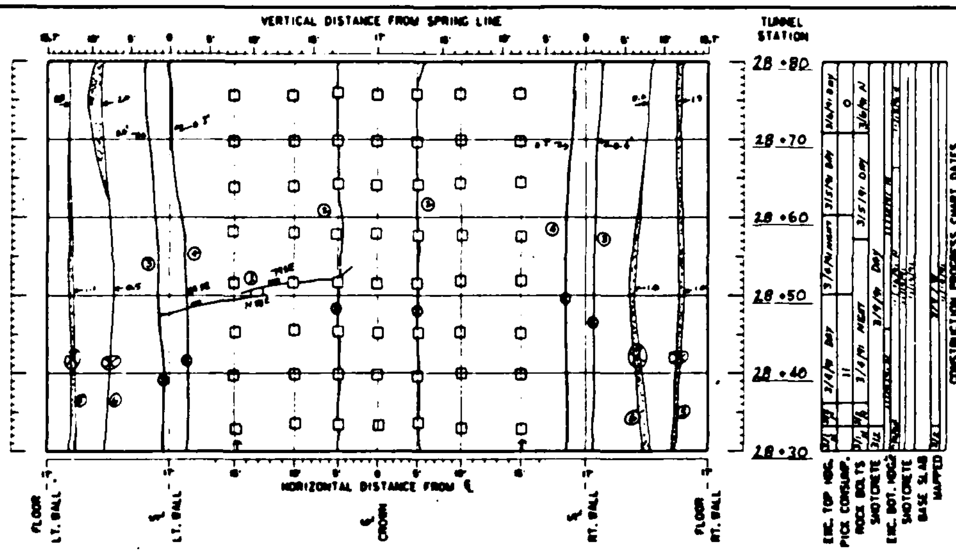
US Army Corps of Engineers

MARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 1

STATION 27+80 TO 28+30

SHEET 37 of 42



LEGEND

ROCK BOLT LOCATION □
SPBX LOCATION △
MPBX LOCATION ●
LOAD CELL LOCATION ◆
TAPE EX ANCHOR ×
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS ●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T1-50 and T1-51.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Joint	T. Shy	N38E, 79-84SE, C4, E2, T2, HL4, M2, R4
2	Bdd pln	T. Shy	Near horizontal, B4
3,4	Ss bdd	T. Shy	Near horizontal, glossy, lt.gr., HS, B3
5,6	ss beds	Ta Shy	SS, vfgrn, lgr, HH w/1, B3/B2, near horizontal, glossy

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

US Army Corps of Engineers

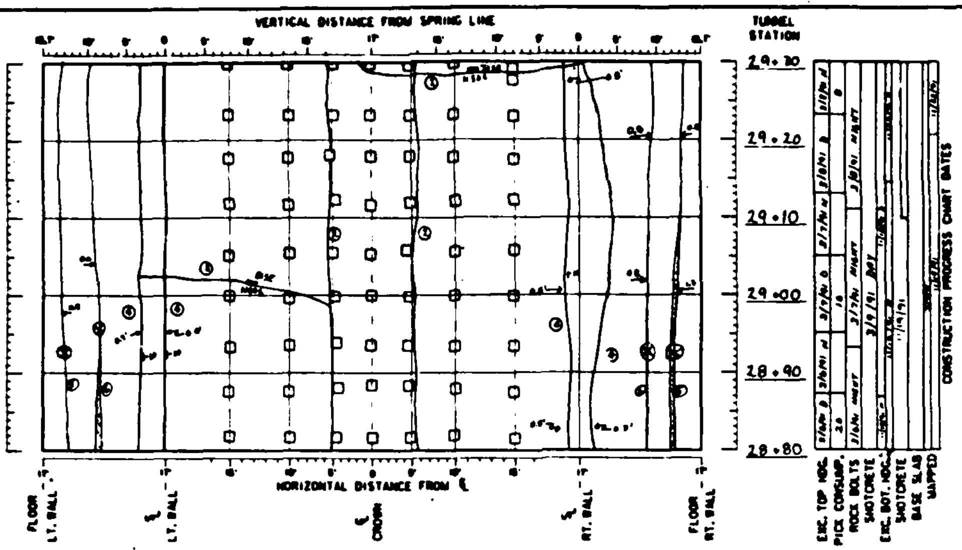
MARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 1

STATION 28+30 TO 28+80

SHEET 38 of 42

PLATE D-25



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER TI-52 and TI-53

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Joint	T Shy	N38E, 75SE, C4, O3, T6, HL4, R2, M4
2	Bed Pln.	T. Shy	B3
3	Joint	T. Shy	N40E, 81SE, C4, A3, T6, HL4, R2, M4
4	Ss bdd	T Shy	Dip 8 18 Sm, gl[illegible], lt gr, H5, B3
5,6	SS bed	Tim Shy	SS, f gm, lgr, B3/B2, H4, W1, near hor. zontal, qtzose

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
3/9/91 1 Extra bolt 29+30 @ Bl.

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

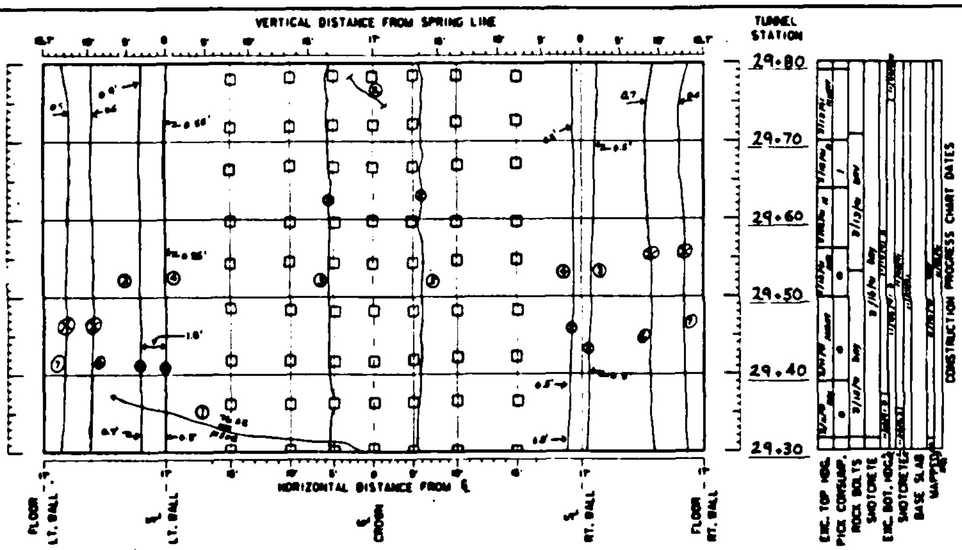
US Army Corps of Engineers

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 1

STATION 28+80 TO 29+30

SHEET 39 OF 42



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER TI-53 and TI-54

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Joint	R Brown	N50E, 76SE, C4, O4, T6, R2, M4
2	Frac	R Brown	C1, O2, T1, R2, M3
3	Ss bdd	R Brown	Near horizontal, lt gr, f grn, H5, B3
4	Ss bdd	R Brown	Near horizontal, lt gr, f grn, H5, B3
5	Bed pln.	R Brown	Near horizontal, B4
6,7	SS beds	Tim Shy	SS, f grn, lgr, H4 W1 B3, near horizontal, qtzose

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
3/13/91 Pins replaced with steel pins on Parcel road [illegible].

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

US Army Corps of Engineers

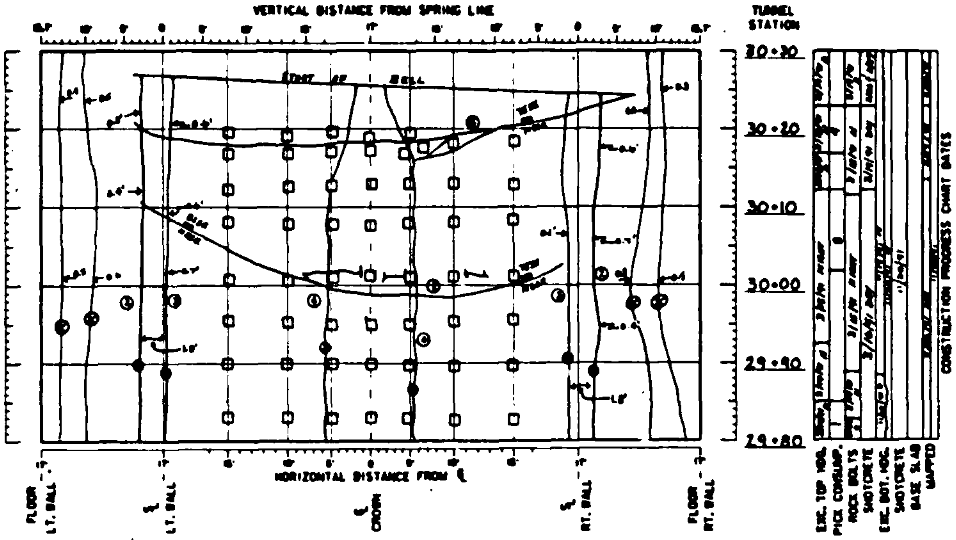
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 1

STATION 29+30 TO 29+80

SHEET 40 OF 42

PLATE D-26



LEGEND

ROCK BOLT LOCATION	□
SPBX LOCATION	▲
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	═
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER TI-54 and TI-55

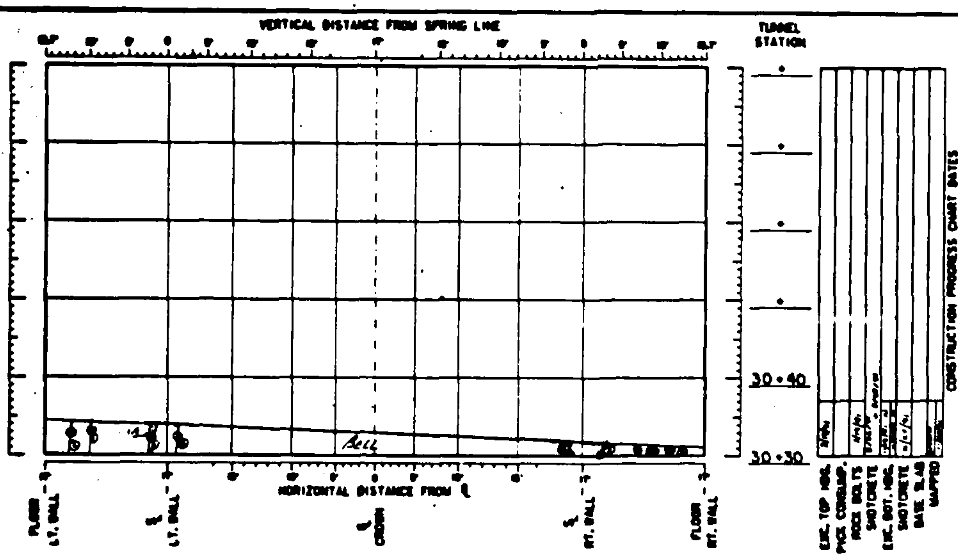
GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Joint	[illegible]	N55-60E, 70-85 SE, C4, 05, T6, R2, H4-5, M4, Fe st.
2, 3	Ss Bdd	[illegible]	near horizontal, lt.gr., f.grn., H5, B3
4	bdd pln.	[illegible]	near horizontal, B4
6	Joint	[illegible]	N61E, 75SE, C4, 05, T6, R2, H4-6, M4

REMARKS. Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
2/[illegible]/81 [illegible] Begin [illegible] sta. 29+[illegible] to 30+12.
[illegible] core hole intercepted @ sta. 30+00
29+90 @ [illegible] rib bolt replaced
Bolts @ sta. 29+[illegible] angled 20° [illegible]
Bolts @ sta. 30+03, 30+[illegible] [illegible] angled [illegible]
Bolts @ sta. 30+[illegible] to 30+[illegible] angled through [illegible]
Bolt angles are measured from vertical
Wall and crown bolts mapped on [illegible] partial surface [illegible]

SCALE 1" = 10'

Geology By	US Army Corps of Engineers — HARLAN DIVERSION GEOLOGIC MAPPING
Drawn By	TUNNEL T- 1
Checked By	STATION 29+80 TO 30+30
Date	SHEET 41 OF 42



LEGEND

ROCK BOLT LOCATION	□
SPBX LOCATION	▲
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	═
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER TI-53.

GEOLOGIC MAPPING LEGEND

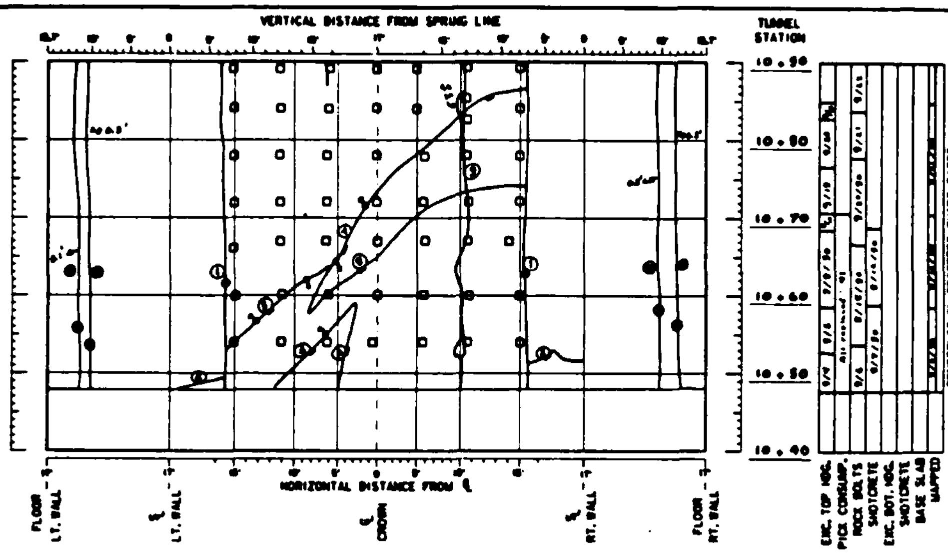
FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1, 2, 4	SS bdg	[illegible]	SS, v.f. grn, l.gr, H4, W1, B3, planar, near horizontal
3	ss bdg	[illegible]	ss, v.f.grn, l.gr, H4, W1, B3, planar, near horizontal

REMARKS. Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
[illegible] [illegible] [illegible] duplicated on [illegible] @ sta. 30+29
Crown bolt locations shown on [illegible] Sheet.

SCALE 1" = 10'

Geology By	US Army Corps of Engineers — HARLAN DIVERSION GEOLOGIC MAPPING
Drawn By	TUNNEL T- 1
Checked By	STATION 30+30 TO 30+40
Date	SHEET 42 OF 42

PLATE D-27



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bed pln	[illegible]	[illegible] horizontal
2	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]
4	J1		[illegible]
5	J1		[illegible]
6	[illegible]		[illegible]
7	J1		[illegible]
8	J1		[illegible]
9	Bed pln	[illegible]	[illegible] horizontal
10	Bdd	TJ	Ss, near horizontal, [illegible]
11	Bdd	TJ	Ss, near horizontal, [illegible]

REMARKS: Tunnel alignment - [illegible]. Mapped geologically using the full periphery method. Orientation of strike symbols approximate. [illegible]

SCALE 1" = 10'

Geology By ______
Drawn By ______
Checked By ______
Date ______

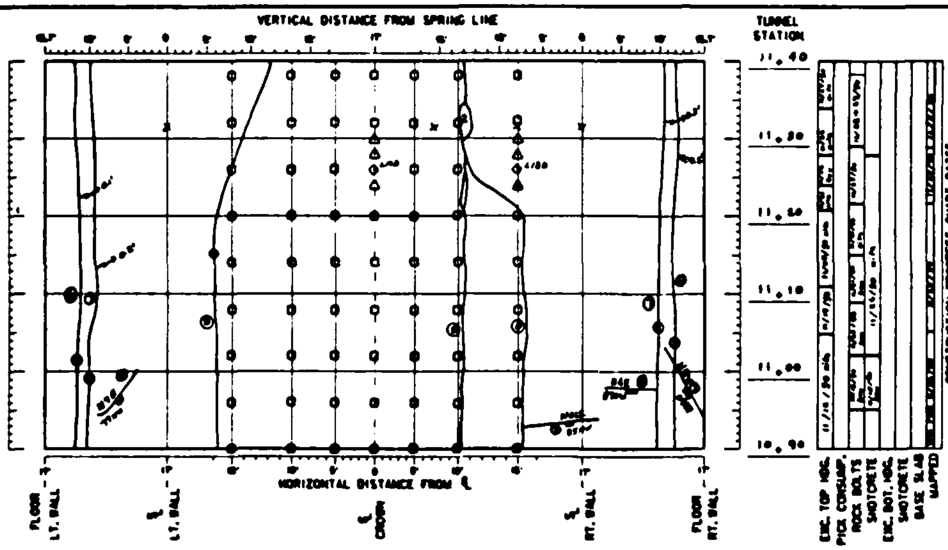
US Army Corps of Engineers

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2

STATION 10+48 TO 10+90

SHEET 1 OF 40



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	J1	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]
3	Joint	TJ	[illegible]
4	Joint	TJ	[illegible]
5	Joint	TJ	[illegible]
6	Bdd	TJ	Ss, near horizontal, [illegible]
7	Bdd	TJ	Ss, near horizontal, [illegible]
8	Bed pln	TJ	Bedding plane.

REMARKS: Tunnel alignment - [illegible]. Mapped geologically using the full periphery method. Orientation of strike symbols approximate. [illegible] ARRAY "D" 11+26, Installed [illegible]-27-90

SCALE 1" = 10'

Geology By ______
Drawn By ______
Checked By ______
Date ______

US Army Corps of Engineers

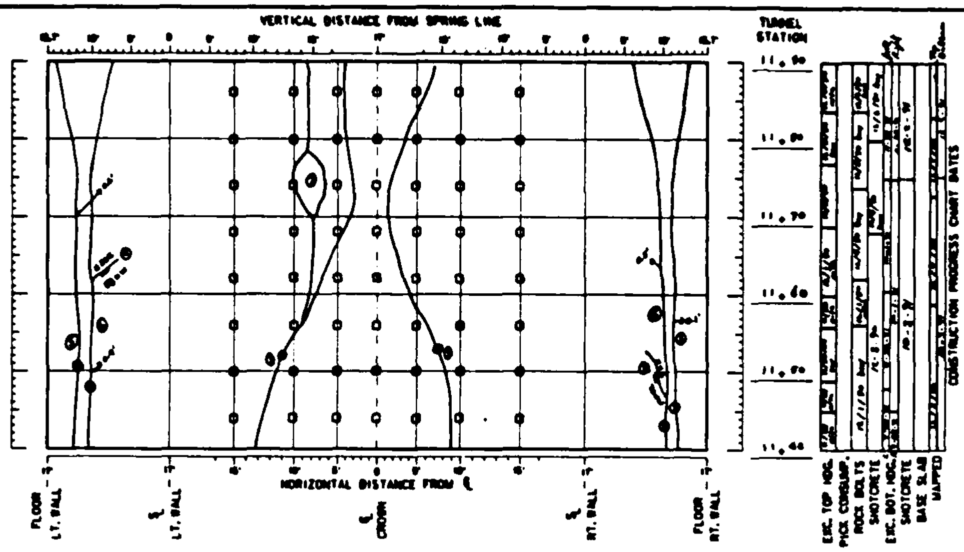
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2

STATION 10+90 TO 11+40

SHEET 2 OF 40

PLATE D-28



LEGEND

- ROCK BOLT LOCATION □
- SPBX LOCATION △
- MPBX LOCATION ●
- LOAD CELL LOCATION ◆
- TAPE EX ANCHOR ×
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS ●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd pln	[illegible]	Bdd pln, horizontal
2	Ss ln	[illegible]	ln
3	Joint	TS	N4E, 70NW, C2, od, T3, B3, HL2, M2
4	Joint	TS	N80E, 58NW, C2, od, T3, B3, HL2, M2
5	Bdd	TS	Ss, lt gy, F grn, H4, W1, B4 — near horizontal
6	Bdd	TS	Ss, lt gy, F grn, H4, W1, B4 — near horizontal

REMARKS: Tunnel Alignment - N 43°24'45"E. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By ______
Drawn By ______
Checked By ______
Date ______

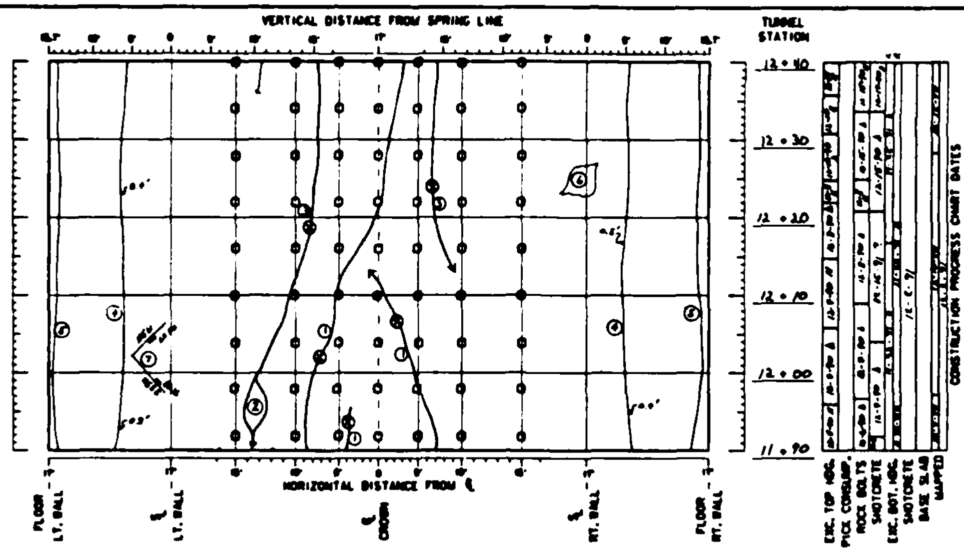
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 2

STATION 11 + 40 TO 11 + 90

SHEET 3 OF 40



LEGEND

- ROCK BOLT LOCATION □
- SPBX LOCATION △
- MPBX LOCATION ●
- LOAD CELL LOCATION ◆
- TAPE EX ANCHOR ×
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS ●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd pln	Tm Shy	Horizontal bedding plane
2	Ss ln	Tm Shy	Sandstone
3	Bdd pln	Tm Shy	Near horizontal bedding plane, C3, T2, HL4, M2
4, 5	Ss beds	TS	Ss, lt gry, f gr, H4, W1, B3, [illegible]
6	Overcut	TS	Roadheader overcut, approx 0.5' deep
7	Fall out	TS	Fracture bounded [illegible], roadheader overcut, approx 1.5 ft deep

REMARKS: Tunnel Alignment - N 43°24'45"E. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.
Dates 96 11/10 - 11/14
Bolts 12+28 & 12+34 Sheared

SCALE 1" = 10'

Geology By ______
Drawn By ______
Checked By ______
Date ______

US Army Corps of Engineers

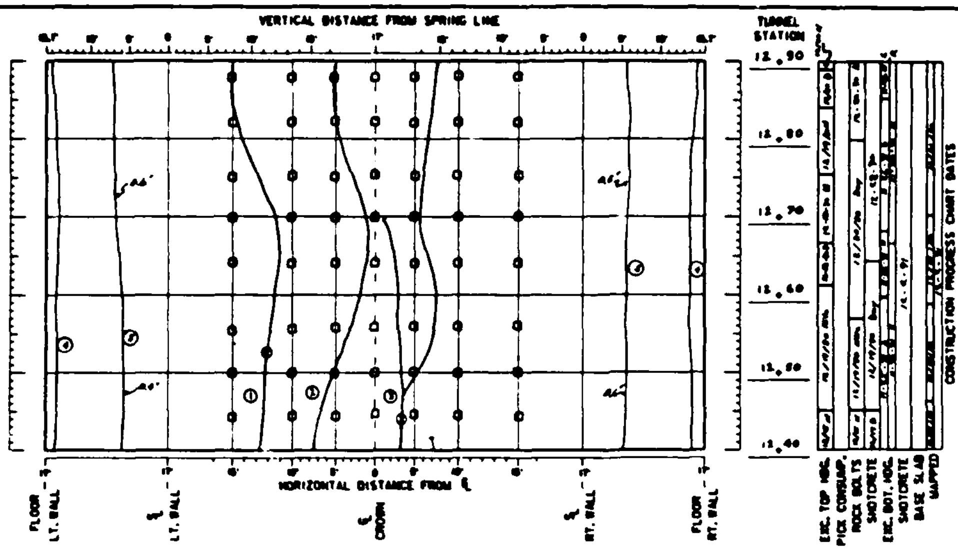
HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 2

STATION 11 + 90 TO 12 + 40

SHEET 4 OF 40

PLATE D-29



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Js	[illegible]	Bdd pln near horizontal
2	Jp		Bdd pln [illegible]
3	Js		Bdd pln near horizontal
4 5	Sh bed	TS	[illegible]

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

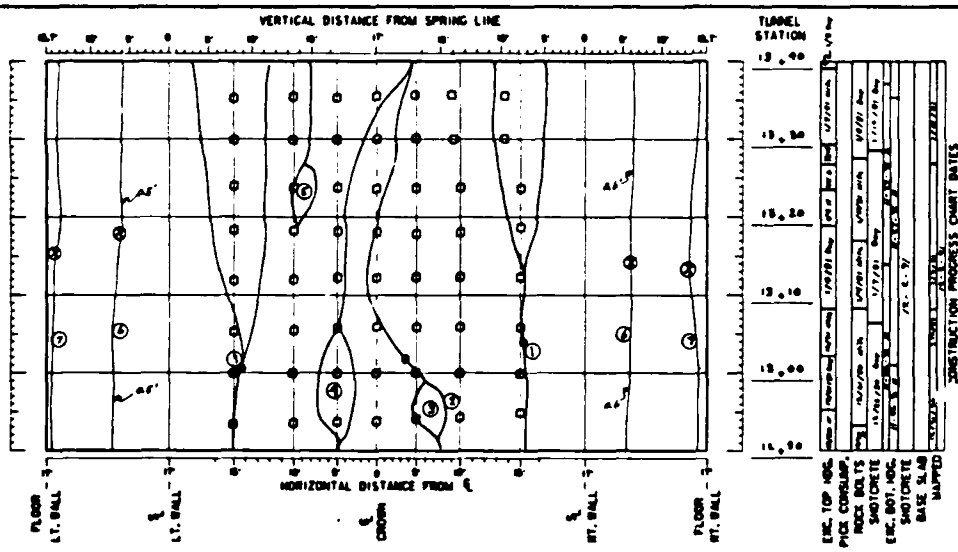
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 2

STATION 12+40 TO 12+90

SHEET 5 of 40



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd pln	[illegible]	[illegible] horizontal
2	Bdd pln		[illegible] horizontal
3	Jn		[illegible]
4	Jn		[illegible]
5	Jn		[illegible]
6 7	Sh bed	TS	[illegible]

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
[illegible]

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

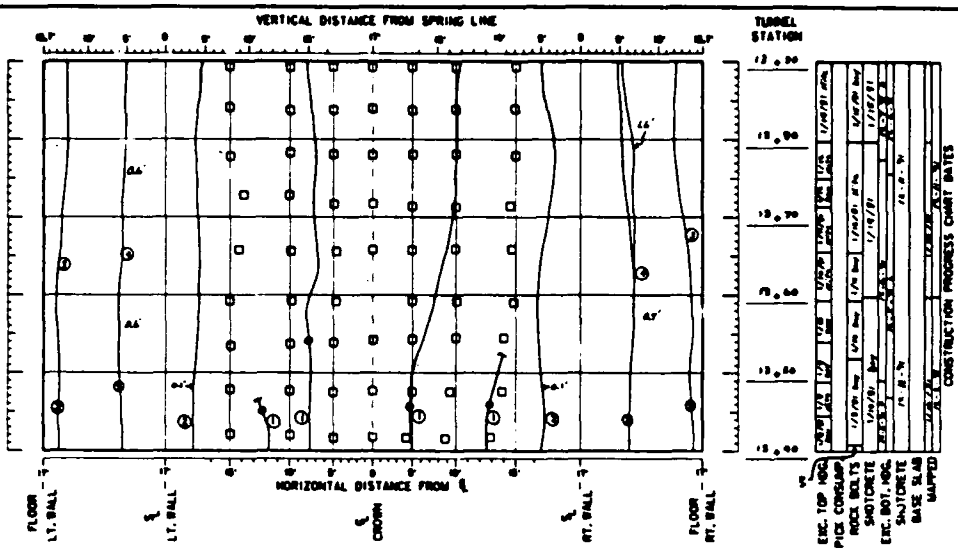
TUNNEL T- 2

STATION 12+90 TO 13+40

SHEET 6 of 40

Pl. 4

PLATE D-30



LEGEND

ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bed pln	[illegible]	[illegible] Horizontal
2	[illegible]	[illegible]	[illegible]
3, 4	Ss bed	TS	Ss [illegible]

REMARKS: Tunnel alignment - [illegible]. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.

[illegible]

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

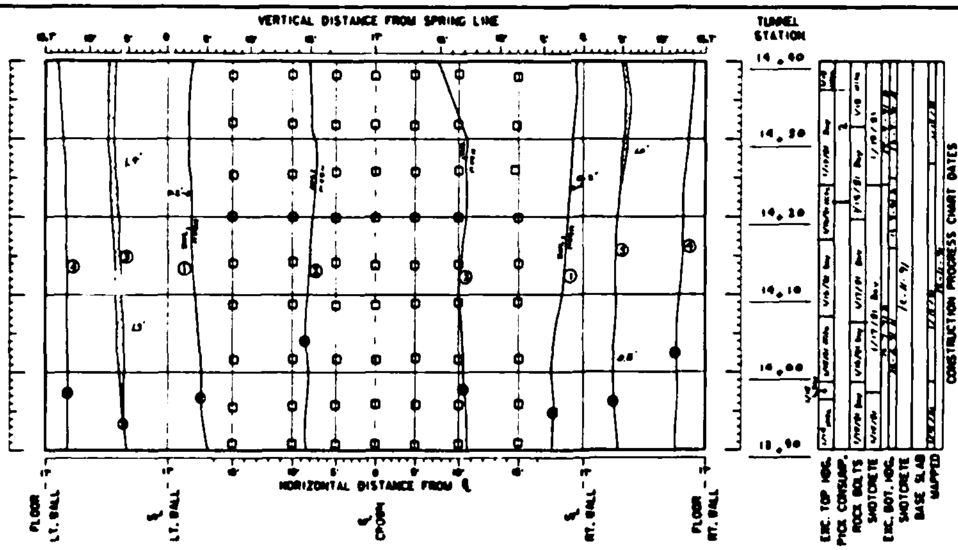
US Army Corps of Engineers

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2

STATION 13+40 TO 13+90

SHEET 7 OF 40



LEGEND

ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bed pln	[illegible]	[illegible] horizontal
2	Bed pln	[illegible]	[illegible]
3	Ss bed	TS	Ss [illegible]
4	Ss bed	TS	Ss [illegible]

REMARKS: Tunnel alignment - [illegible]. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers

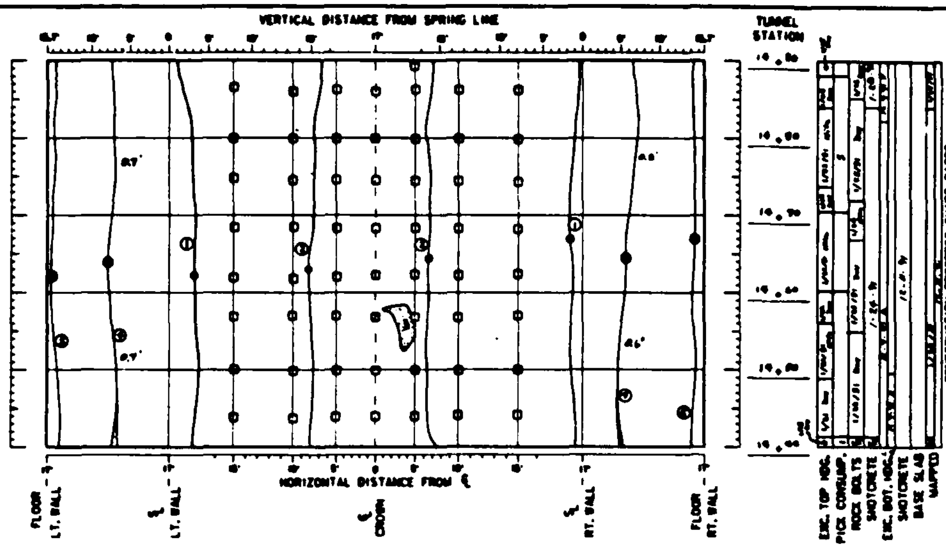
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2

STATION 13+90 TO 14+40

SHEET 8 OF 40

PLATE D-31



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	Bed pln	[illegible]	Horizontal
3	[illegible]	[illegible]	[illegible]
4	Ss bed	TS	[illegible]
5	Ss bed	TS	[illegible]

REMARKS: Tunnel alignment - [illegible]. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

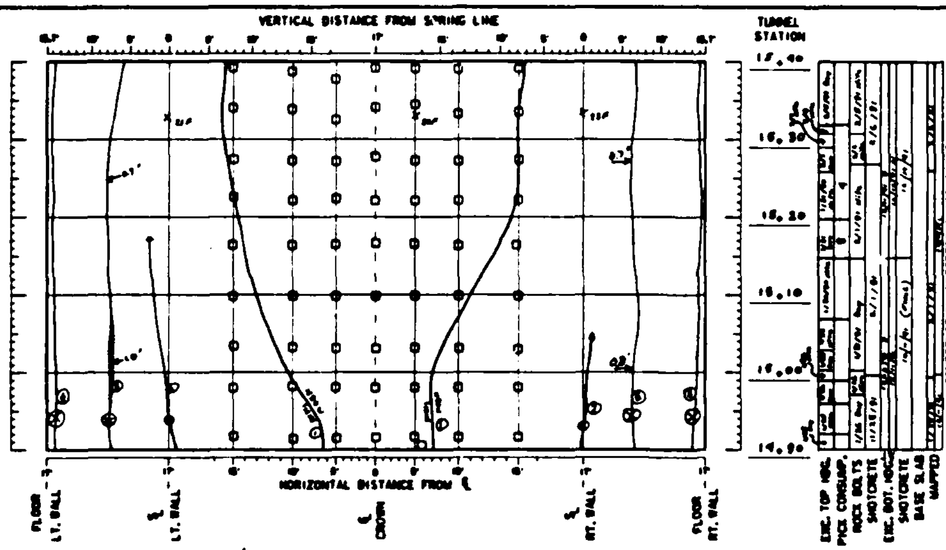
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 2

STATION [illegible] TO [illegible]

SHEET 9 OF 40



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bed pln	[illegible]	[illegible]
2	Bed pln	[illegible]	[illegible] Horizontal
3	Ss bed	[illegible]	[illegible] near horizontal [illegible]
4	Ss bed	[illegible]	[illegible] near horizontal [illegible]

REMARKS: Tunnel alignment - [illegible]. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.
[illegible]
[illegible]
[illegible]
[illegible]

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

US Army Corps of Engineers

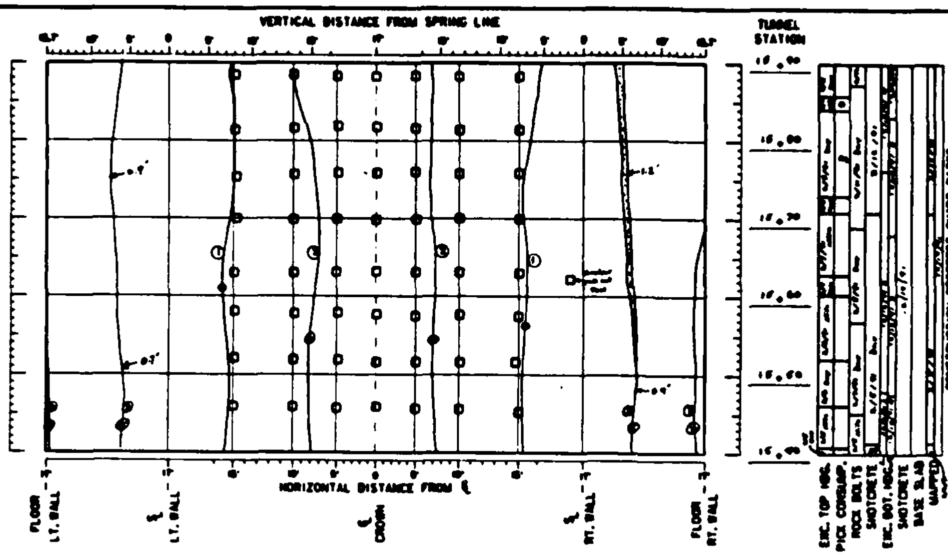
HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 2

STATION [illegible] TO [illegible]

SHEET 10 OF 40

PLATE D-32



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	bed pln	[illegible]	B4/B3 [illegible]
3	ss bed	TWShy	ss, v f grn, l gr, B3/B2, H4, W1, near horizontal, gr/seam
4	ss bed	TWShy	ss, v f grn, l gr, B4, H4, W1, near horizontal, gr/seam

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

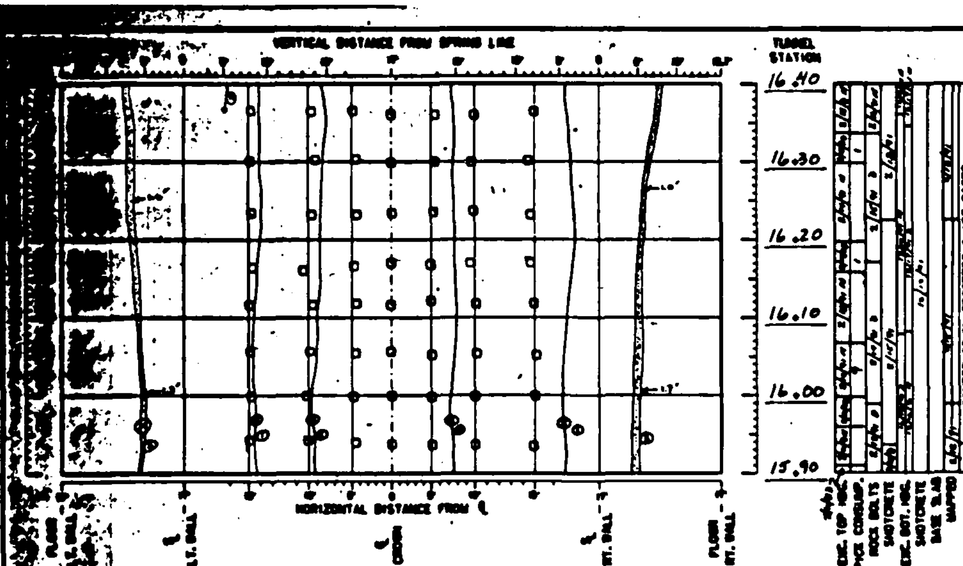
US Army Corps of Engineers

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2

STATION 15+40 TO 15+90

SHEET 11 OF 40



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	bdg pln	[illegible]	B4, bedding planes, near horizontal (slight dw dip)
3	ss bed	TWShy	ss, v f grn, l gr, B3, H4, W1, near horizontal, gr/seam
4	ss bed	TWShy	ss, v f grn, l gr, B3, H4, W1, near horizontal, gr/seam

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers

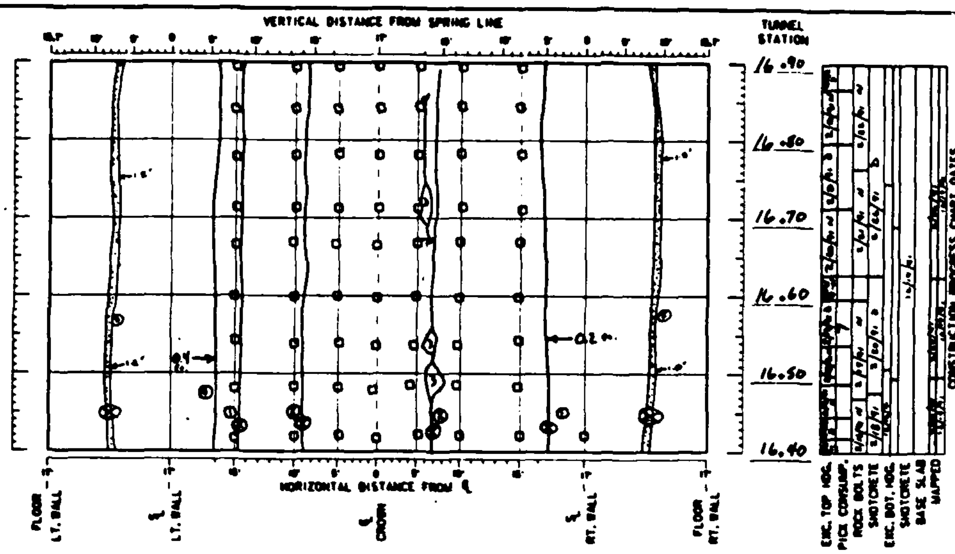
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2

STATION 15+90 TO 16+40

SHEET 12 OF 40

PLATE D-33



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1, 2	Bddg Pln	Tm Shg	B3 Morris
3	Lens	Tm Shg	Ss, dk gry, nodul profile
4	Bddg Pln	Tm Shg	B4, horizontal, l gry, Ss
5	Bdg pln	Tm Shg	[illegible], l gr, B3, B4, [illegible], near horizontal, [illegible]

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
12/12/91 — T=48°F, Desco [illegible] @ 0900
2/26/91 — T=50°F, partial [illegible] at 1100
2/26/91 -

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

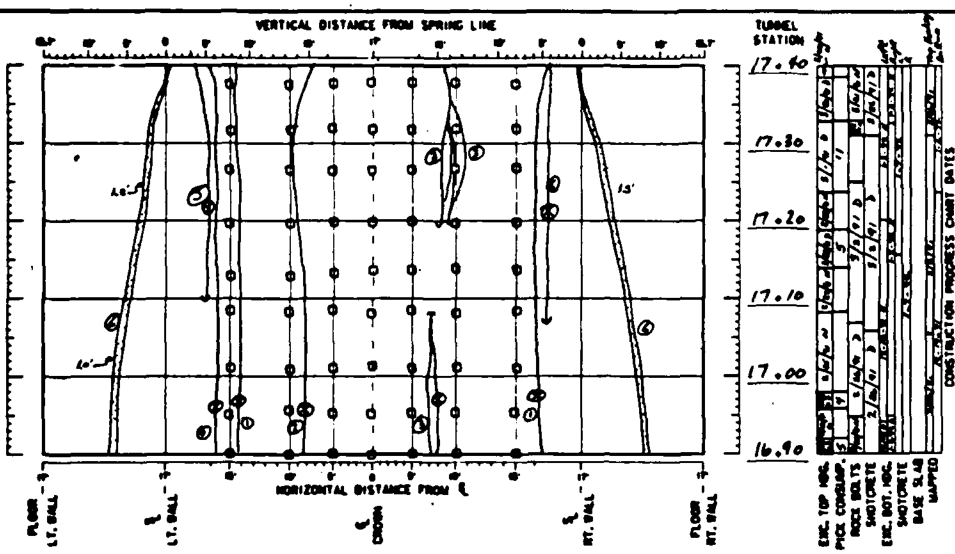
US Army Corps of Engineers

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2

STATION 16.40 TO 16.90

SHEET 13 OF 40



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1, 2	Bddg pln	[illegible]	A3 Horizontal
3	[illegible]	}	Ss, [illegible], lt gr. Horizontal
4	Bddg pln	}	Ss, lt gr, B4 Horizontal
5	Bddg pln	[illegible]	[illegible], lt gr, [illegible] Horizontal
6	[illegible]	T3	[illegible]

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
3/5/91 — Desco down, [illegible] 17+33
3/6/91 — Desco still down, [illegible] 17+33

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

US Army Corps of Engineers

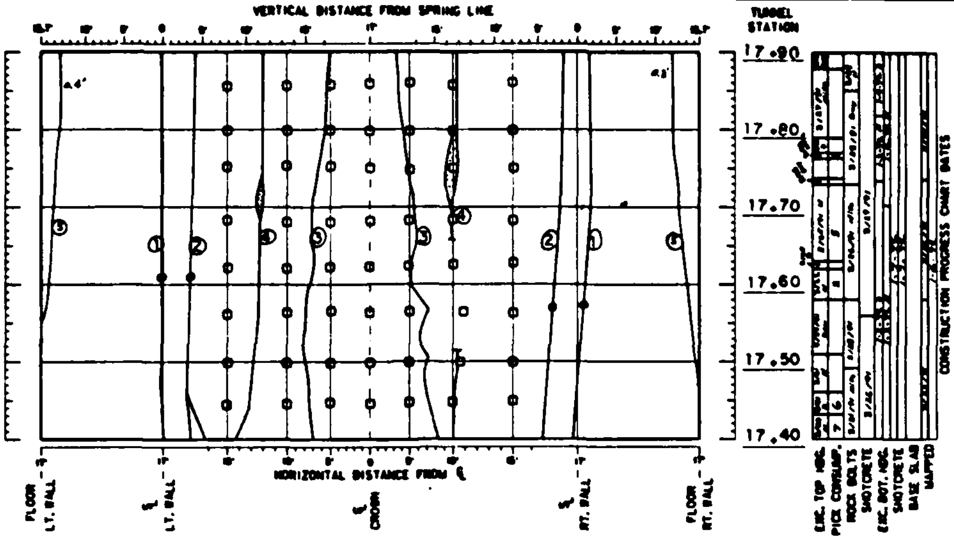
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2

STATION 16.90 TO 17.40

SHEET 14 OF 40

PLATE D-34



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	bdd pln	[illegible]	BS [illegible]
2	bdd pln	[illegible]	BS [illegible]
3	bdd pln	[illegible]	BS
4	bdd pln	[illegible]	BS [illegible]
5	Ss bed	TS	[illegible]

REMARKS: Tunnel Alignment - N 43°24'45"W. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.
[illegible]

SCALE 1" = 10'

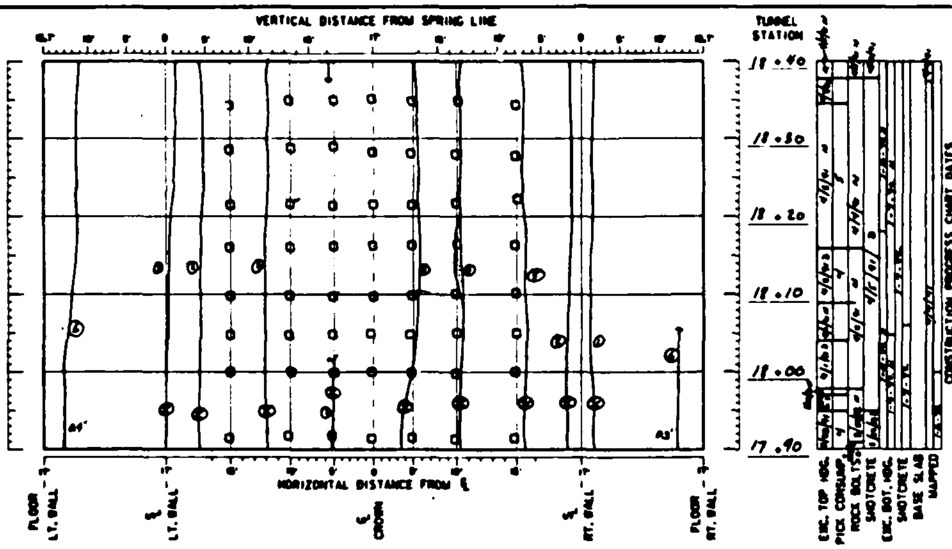
Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers
HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 2

STATION 17+40 TO 17+90

SHEET 15 OF 40



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	[illegible]	[illegible]	[illegible]
2	Ss bdd	[illegible]	[illegible]
3	Ss bdd	[illegible]	[illegible]
4	Ss bdd	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]
6	Ss bed	TS	[illegible]

REMARKS: Tunnel Alignment - N 43°24'45"W. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.
[illegible]

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

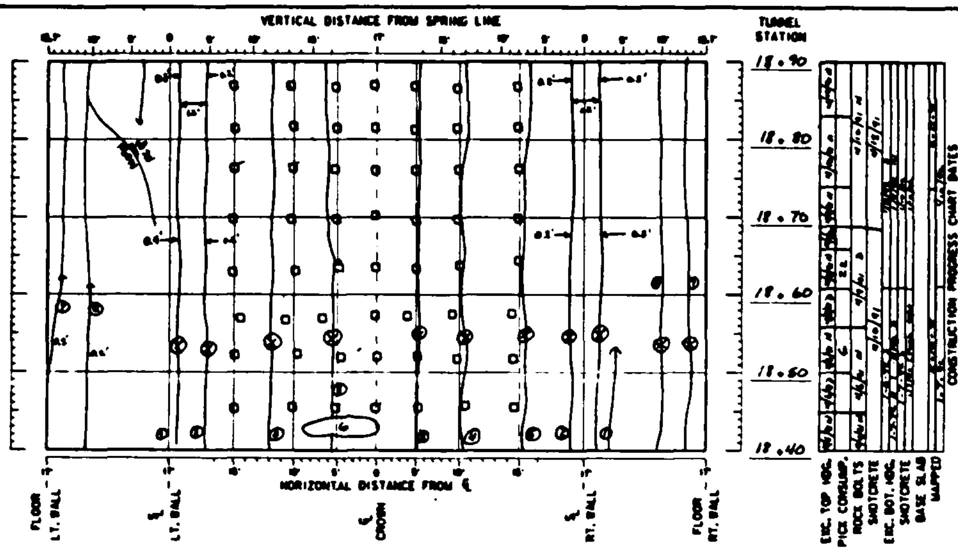
US Army Corps of Engineers
HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 2

STATION 17+90 TO 18+40

SHEET 16 OF 40

PLATE D-35



LEGEND

ROCK BOLT LOCATION	□
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T2-16/T2-17

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	[illegible]	[illegible]	[illegible] — near horizontal
3	[illegible]		[illegible]
4	[illegible]		[illegible], near horizontal
5	[illegible]	[illegible]	[illegible], near horizontal
6	[illegible]	[illegible]	[illegible]
7	[illegible]		[illegible]
8	[illegible]		

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
[illegible] - 18+70 - [illegible] not installed until later. Tunnel profile [illegible] facing in
[illegible] - 18+75 to 18+83 - partial excavation left side only - [illegible]
[illegible] - [illegible]

SCALE 1" = 10'

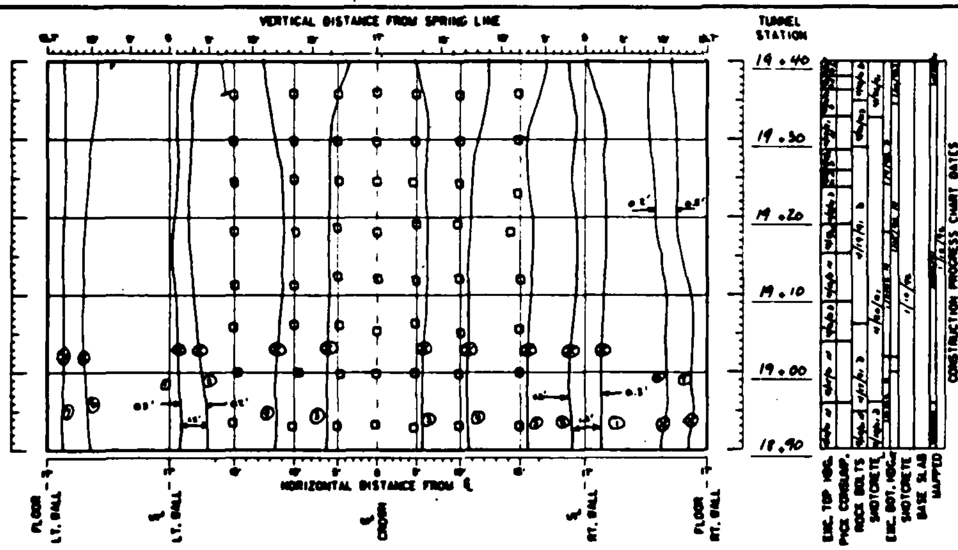
Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2

STATION 18+40 TO 18+90

SHEET 17 OF 40



LEGEND

ROCK BOLT LOCATION	□
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T2-17/T2-18

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	[illegible]	[illegible]	[illegible] near horizontal
3	[illegible]		[illegible], near horizontal
4	[illegible]		[illegible], near horizontal
5	[illegible]	[illegible]	[illegible], near horizontal
6	[illegible]	[illegible]	[illegible], near horizontal, [illegible]
7	[illegible]	[illegible]	[illegible], near horizontal, [illegible]

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

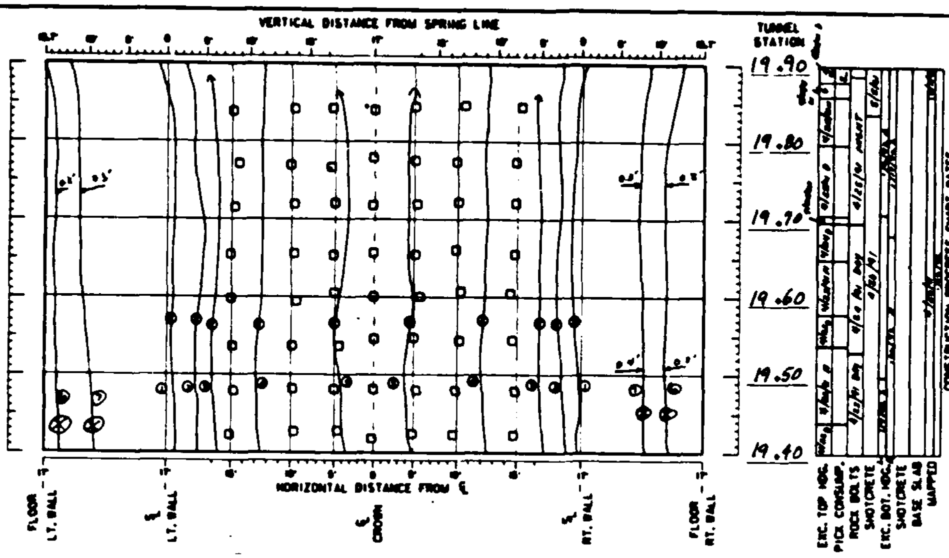
US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2

STATION 18+90 TO 19+40

SHEET 18 OF 40

PLATE D-36



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T2-18 & T2-19.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd pln	T. SHY	Near horizontal, B3
2	Bdd pln	T. SHY	Near horizontal, lt gr stks, 0.3 ft thick / B2
3	Bdd pln	T. SHY	Near horizontal, lt gr stks, 0.6 ft thick / B3
4	Bdd pln	T. SHY	Near horizontal, B3
5	Bdd pln	T. SHY	Near horizontal, B3
6	SS bed	Tim Shy	ss, v f gm, l gr, H4, W2, B3, near horizontal, grease
7	SS bed	Tim Shy	ss, v f gm, l gr, H4, W2, B3, near horizontal, grease

REMARKS: Tunnel alignment - N 43°24'45"E. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

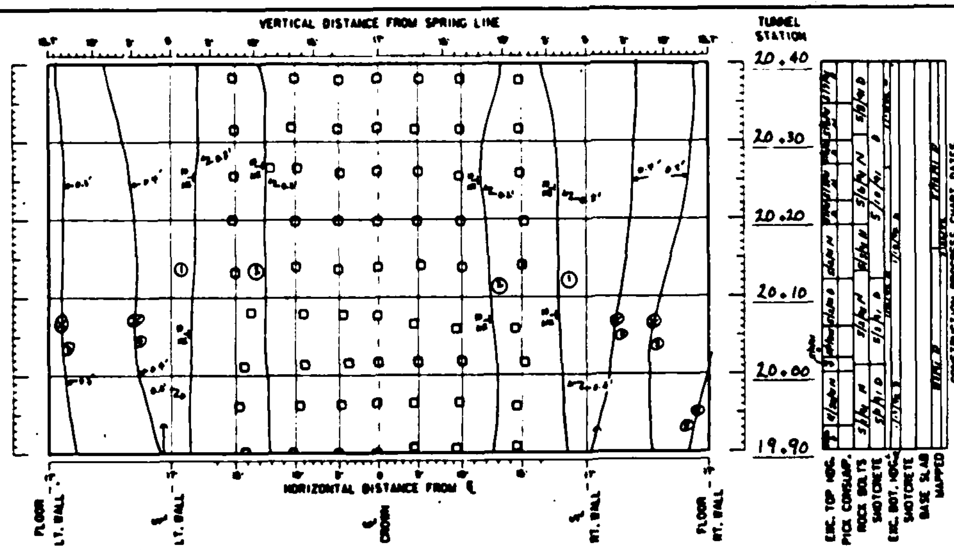
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 2

STATION 19+40 TO 19+90

SHEET 19 OF 40



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T2-19 & T2-20.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd pln	T SHY	Dips 10° NE, grease zone w/thd of gr sist, lt gr, B3
2	Bdd pln	T SHY	Dips 10° NE, grease zone w/thd of gr sist, lt gr, B3
3,4,5	ss bd	Tim Shy	ss, v f gm, l gr, H4, W2, B3, near horizontal, grease

REMARKS: Tunnel alignment - N 43°24'45"E. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.
5/3 - Oil show around face. Tunnel profile at 20+00, at 20+15
5/6 - Bolts stressed at 20+20 to 22 KIPS

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

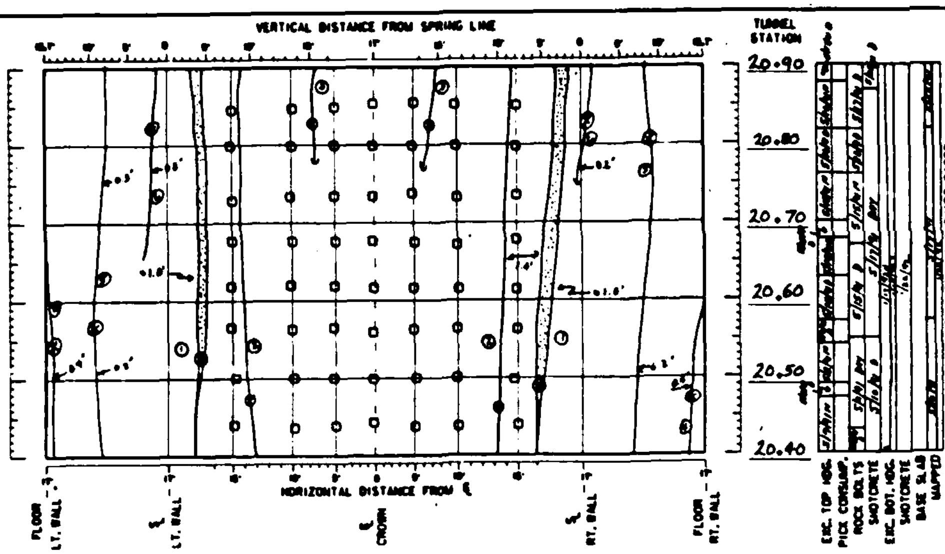
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 2

STATION 19+90 TO 20+40

SHEET 20 OF 40



LEGEND

- ROCK BOLT LOCATION □
- SPBX LOCATION △
- MPBX LOCATION ●
- LOAD CELL LOCATION ◆
- TAPE EX ANCHOR ×
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS ●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T2-20 / T2-21.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd. pln.	T. Sky	Near horizontal, lt. gr., f. grn., laminated, B3.
2	Bdd. pln.	T. Sky	Near horizontal, lt. gr., f. grn., laminated, B3.
3	Bdd. pln.	T. Sky	Near horizontal, lt. gr., f. grn., laminated, B4.
4	ss bed	T. Sky	ss, v f grn, l gr, M4 wl, B3, near horizontal, grains
5	ss bed	T. Sky	ss, v f grn, l gr, M4 wl, B3 near horizontal, grains
6	ss bed	T. Sky	ss, v f grn, l gr, M4 wl, B3 near horizontal, grains

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
5/8/91 - Dosco down 1300-1730 hrs

SCALE 1" = 10'

Geology By:
Drawn By:
Checked By:
Date:

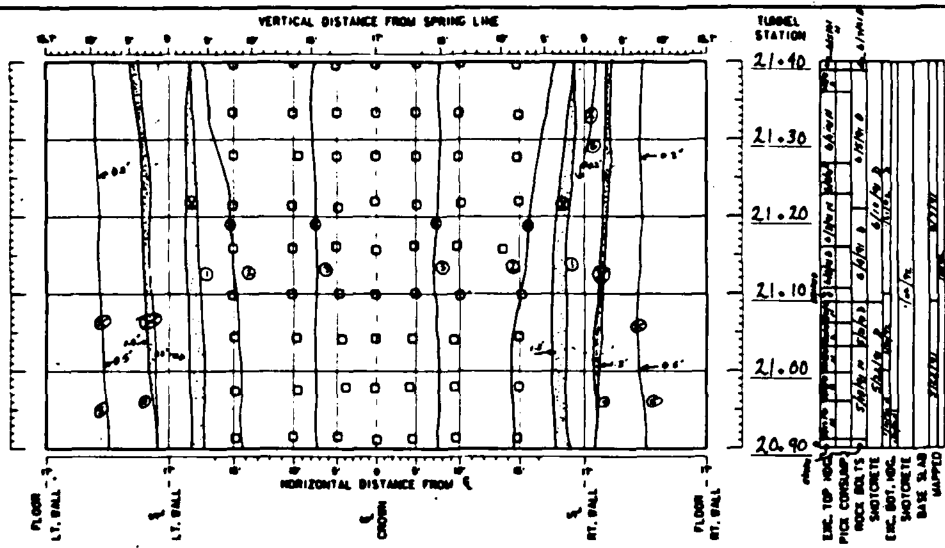
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 2

STATION 20+40 TO 20+90

SHEET 21 OF 40



LEGEND

- ROCK BOLT LOCATION □
- SPBX LOCATION △
- MPBX LOCATION ●
- LOAD CELL LOCATION ◆
- TAPE EX ANCHOR ×
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS ●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T2-21 / T2-22.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd. pln.	T. Sky	Ss, near horizontal, 1.3' thick zone, laminated, f. grn. B3
2	Bdd. pln.	T. Sky	Ss, near horizontal, laminated, f. grn., B3
3	Bdd. pln.	T. Sky	Near horizontal, laminated, lt. gr., f. grn., B4
4	ss bed	T. Sky	ss, v f grn, l gr, B3/B4, M4 wl, near horizontal
5	ss bed	T. Sky	ss, v f grn, l gr, B4, M4 wl, near horizontal

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
5/21/91 - Dosco o/s due to turntable problems

SCALE 1" = 10'

Geology By:
Drawn By:
Checked By:
Date:

US Army Corps of Engineers

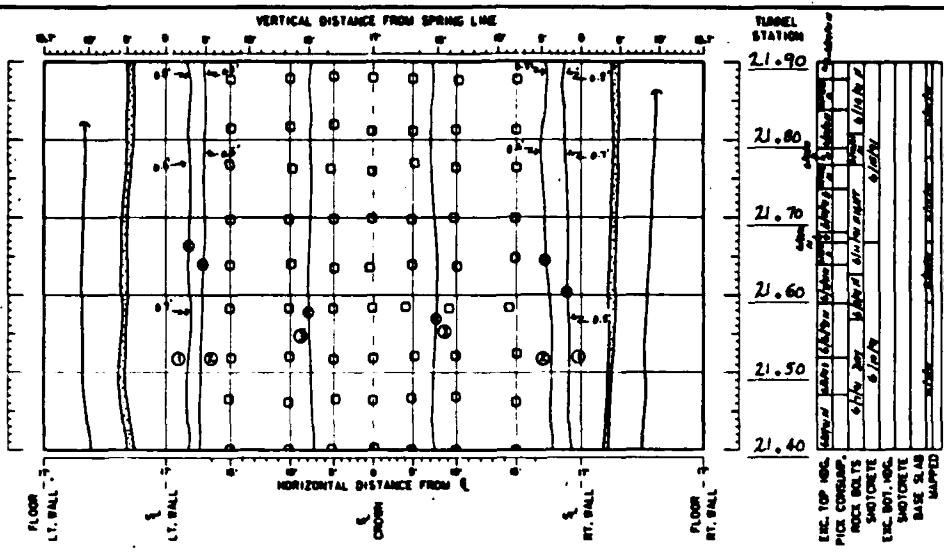
HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 2

STATION 20+90 TO 21+40

SHEET 22 OF 40

PLATE D-38



LEGEND

ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd	T. Shy	Ss, near horizontal, lt gr, f gr, massive, M4, B3
2	Bdd	T. Shy	Ss, near horizontal, lt gr, f gr, laminated, massive, M4, B3
3	Bdd pln	T. Shy	Near horizontal, lt gr, Bx

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
6/6/— Sumped in left side, two bolts above spring line installed. Others installed late.
Profile at 21+45

6/—/— Dosco down: 5 pick blocks broken
6/—/— Dosco down: burned out cutting head motor
6/—/— ℄ and left crown bolt installed late at 21+70

Scale 1" = 10'

Geology By
Drawn By
Checked By
Date

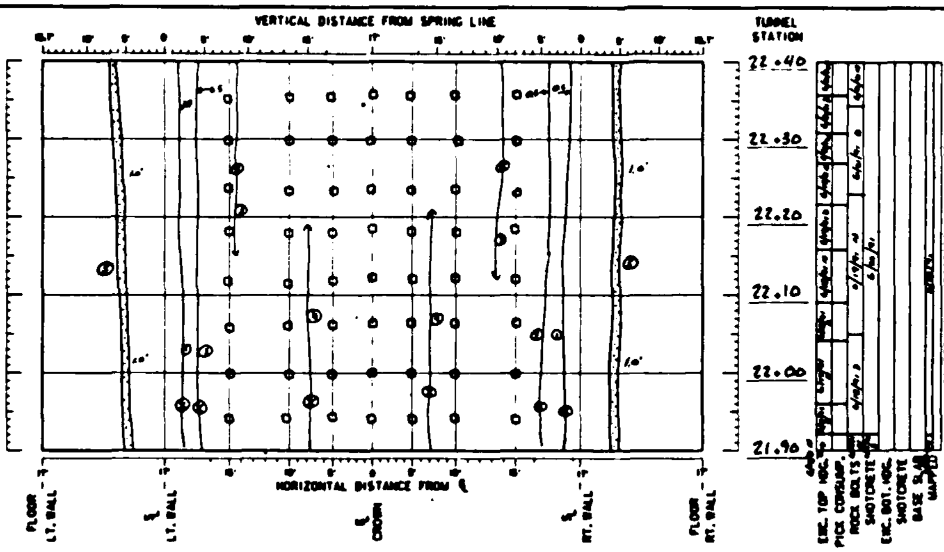
US Army Corps of Engineers

MARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2

STATION 21+40 TO 21+90

SHEET 23 OF 40



LEGEND

ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1, 2	Bdd pln.	T. Shy	Sandstone, lgry, gtsm, f gr, laminae, near horizontal, B3
3, 4	Bdg Pn	T. Shy	lgry, Ss, f gr, Bx, Near horizontal
5		R.Am	Sandstone, lt gry, gtsm, lt f gr, hard, thickness indicated

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
6/—/— Dosco operating in low gear this week, both shifts

Scale 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers

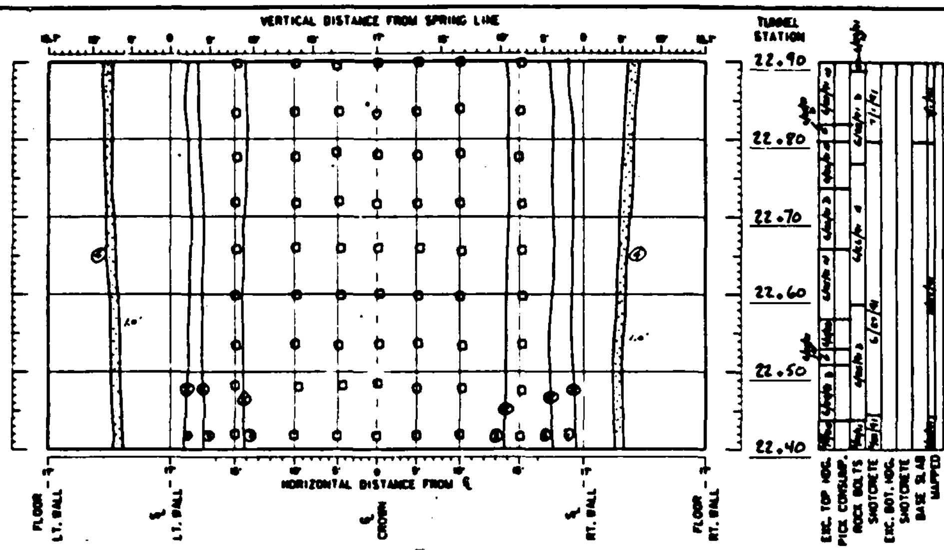
MARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2

STATION 21.90 TO 22.40

SHEET 24 OF 40

PLATE D-39



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	Corr. bd	Tm Shy	Ss, lgry, gtzose, f grn, laminae, near horizontal, 89
3	Bdg pln	Tm Shy	lgry, cm grn, slit, 84, near horizontal
4	Ss cl	[illegible]	Ss lgy gtzose, at grn, bl. thickness indicated

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
6/27/91 - Oil in floor: 22+85 to 22+70 (face)

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

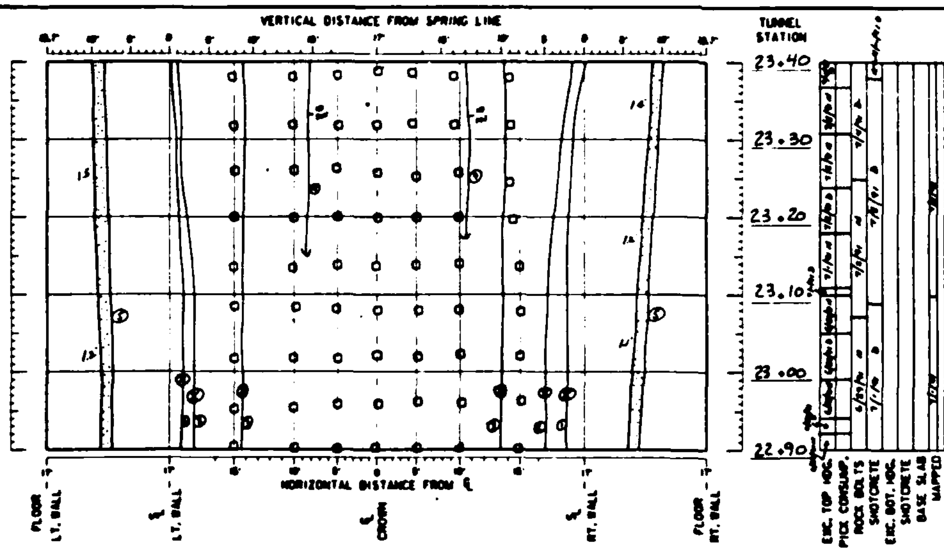
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 2

STATION 22+40 TO 22+90

SHEET 25 OF 40



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdg Pln	Tm Shy	84, N4, Ss, lgry, gtzose, f grn lam, near horizontal
2	Bdg Pln	/	84, N4, Ss, lgry, gtzose, f grn lam, near horizontal
3	Bdg Pln	/	84, N4, Ss, lgry, gtzose, f grn lam, near horizontal
4	Bdg Pln	Tm Shy	84 fcu, OB, c3, Td, N4, Ml, Dips 18° NW
5	Ss cl	[illegible]	Ss, K gy, gtzose, f grn, bl. thickness indicated

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
7/8 - tunnel profile. Some rock fallout near shotcrete margins, sta. 23+15, from crown

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers

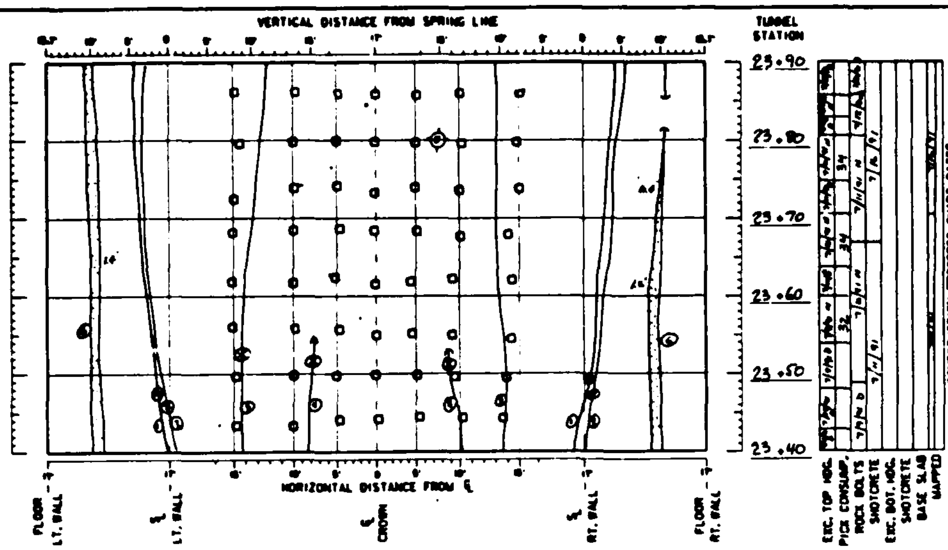
HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 2

STATION 22+90 TO 23+40

SHEET 26 OF 40

PLATE D-40



LEGEND

ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	C sm bd	Tm Sh	Ss, lgr, fgrn, gtnam, HY, BS, near horizontal
3,4	Bed Pln	S	BY, lgr, near horizontal
5	Core hole	Tm Sh	Core hole CH-3, flowing water < 1 gpm
6	Sc bd	[illegible]	Ss bd, N gr, v fgrn bd, thickness indicated

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
7/1/91 - Shape heavily skewed - sta. 23+67 "⌒"

Geology By
Drawn By
Checked By
Date

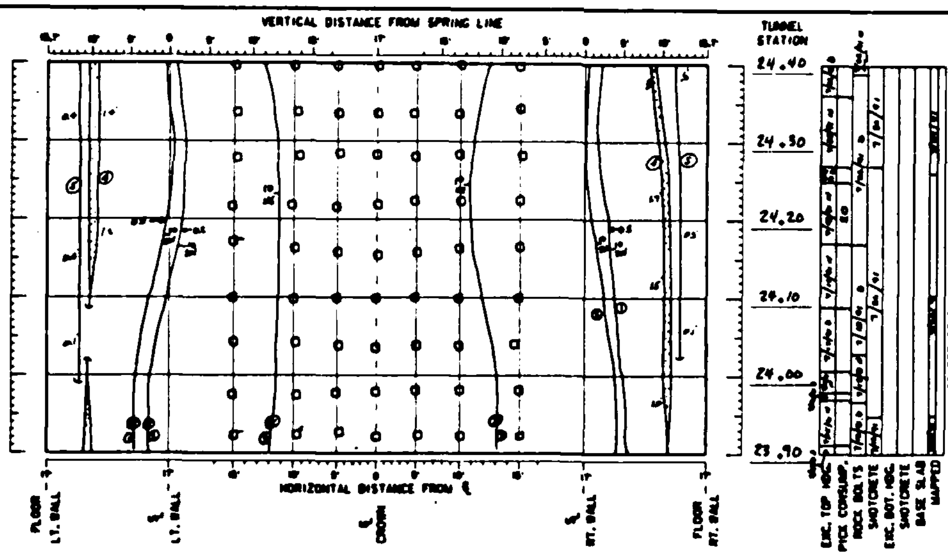
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 2

STATION 23+40 TO 23+90

SHEET 27 OF 40



LEGEND

ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	C sm bd	Tm Sh	Ss, lgr, fgrn, gtnam, HY, BS, near horizontal [illegible]
3	Bed Pln	Tm Sh	BY, lgr, near horizontal
4,5	Sc bd	[illegible]	Ss bd, N gr, v fgrn bd, thickness indicated

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
[illegible] - Jasso out of service. Crown left in place [illegible] to 24+10 until 7/06/91

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers

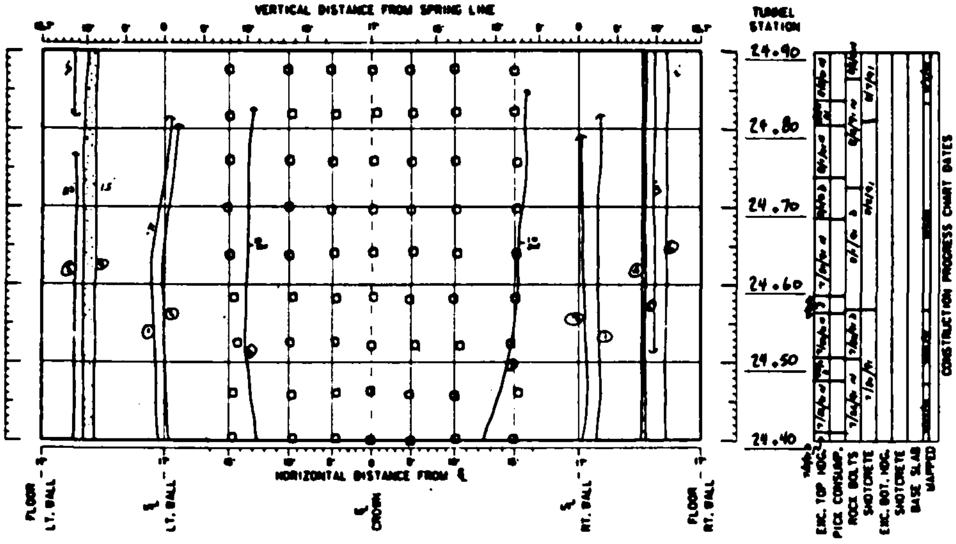
HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 2

STATION 23+90 TO 24+40

SHEET 28 OF 40

PLATE D-41



LEGEND

ROCK BOLT LOCATION	□
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	☰
SEEPAGE	♀
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ________.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	[illegible]	[illegible]	Ss, f gm, BD, l gr, [illegible], f gm [illegible], horizontal [illegible]
			[illegible]
3	[illegible]	[illegible]	[illegible] l gr, [illegible]
4,5,6	[illegible]	[illegible]	[illegible]

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

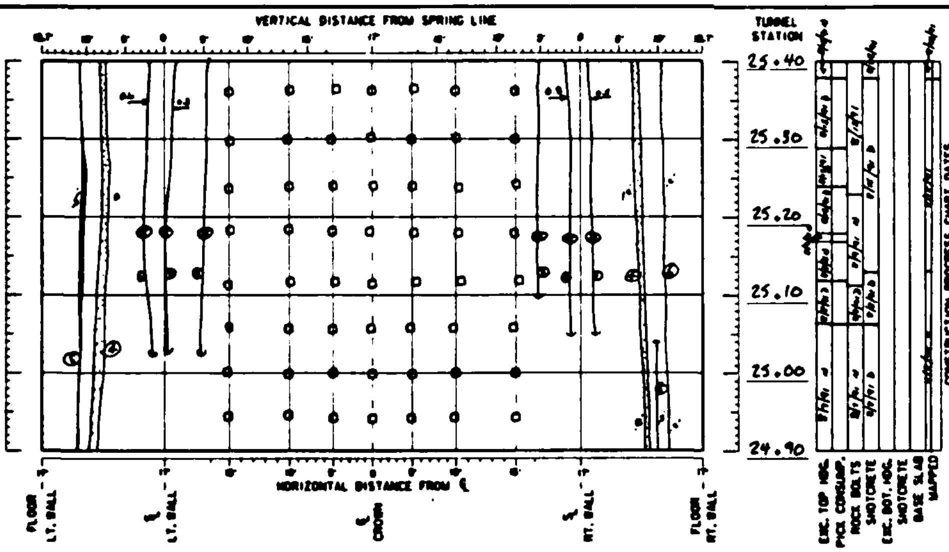
US Army Corps of Engineers

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2

STATION 24+40 TO 24+90

SHEET 29 OF 40



LEGEND

ROCK BOLT LOCATION	□
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	☰
SEEPAGE	♀
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ________.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	[illegible]	[illegible]	Ss, l gr, f gm, [illegible], [illegible] horizontal, BD
3	[illegible]	[illegible]	Bt, l gr.
4,5,6	[illegible]	[illegible]	[illegible]

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

US Army Corps of Engineers

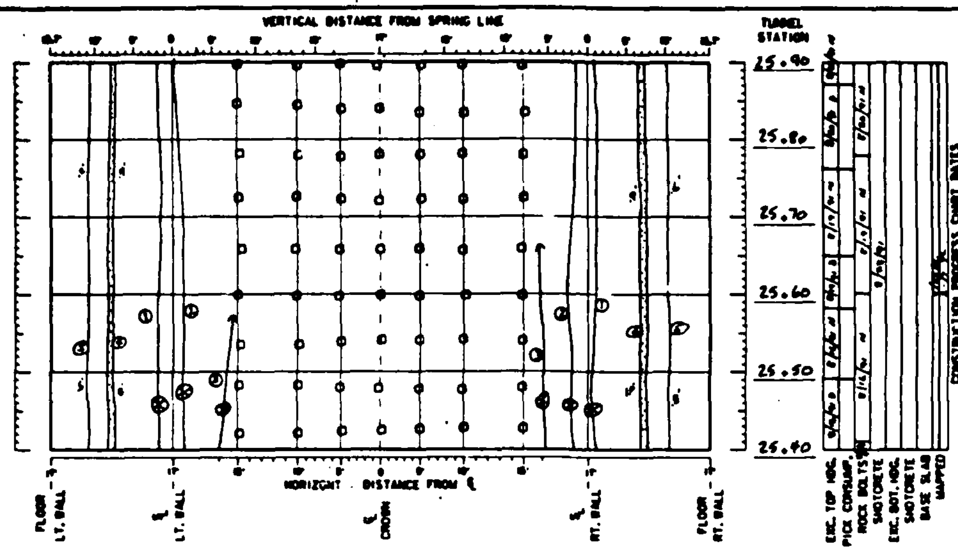
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2

STATION 24+90 TO 25+40

SHEET 30 OF 40

PLATE D-42



LEGEND

ROCK BOLT LOCATION	□
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

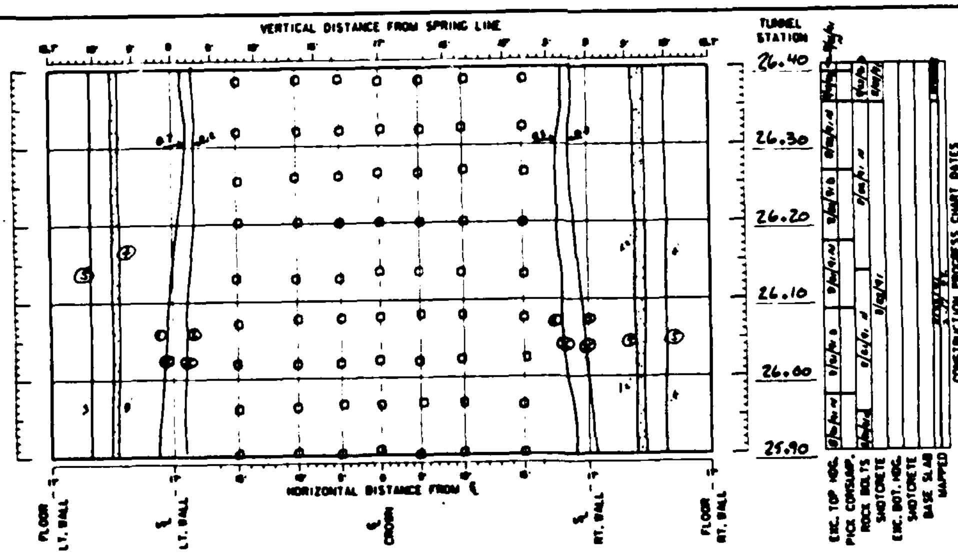
GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	Cgm bed	[illegible]	Ss, lgr, fgm gtstd, [illegible], near horizontal
3	[illegible]	[illegible]	[illegible], lgr
4,5	Ss bed	[illegible]	[illegible]

REMARKS: Tunnel alignment - N 43°24'45"E. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By	US Army Corps of Engineers — HARLAN DIVERSION GEOLOGIC MAPPING
Drawn By	TUNNEL T- 2
Checked By	STATION 25.40 TO 25.90
Date	SHEET 31 OF 40



LEGEND

ROCK BOLT LOCATION	□
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

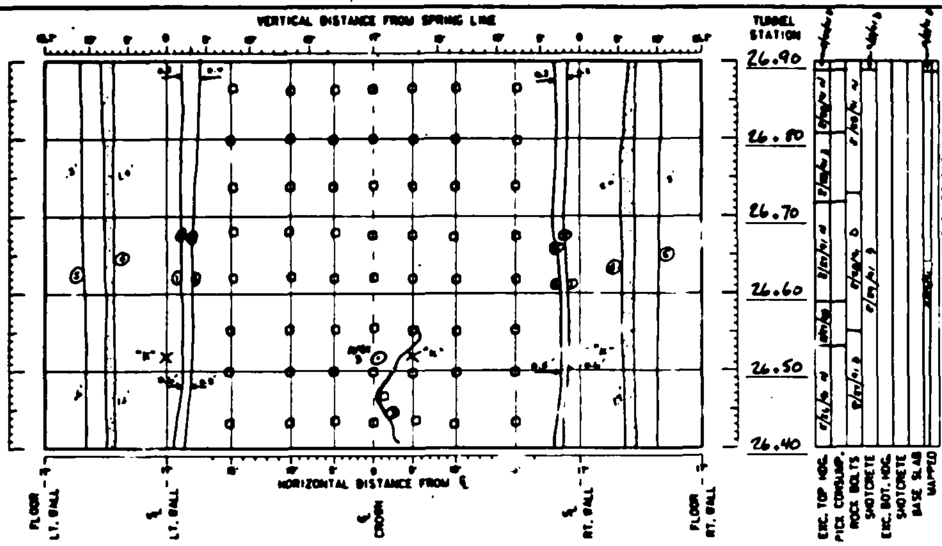
GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,3	Cgm bed	[illegible]	Ss, fgm, lgr, bd, [illegible], near horizontal, [illegible]
4,5	Ss bed	[illegible]	[illegible]

REMARKS: Tunnel alignment - N 43°24'45"E. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By	US Army Corps of Engineers — HARLAN DIVERSION GEOLOGIC MAPPING
Drawn By	TUNNEL T- 2
Checked By	STATION 25.90 TO 26.40
Date	SHEET 32 OF 40



LEGEND

ROCK BOLT LOCATION	□
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	[illegible]	[illegible]	Ss. f. gn. lgc. vhd., gtsme, N4 W5, 82 near horizontal
3	[illegible]	[illegible]	Thin coal - mantle gouge from roadheader
4,5	[illegible]	[illegible]	[illegible]

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
[illegible] - [illegible] bolt sta 26+47, top of crown.
[illegible] - Installed 3-point TX array "K" at sta 26+52.

SCALE 1" = 10

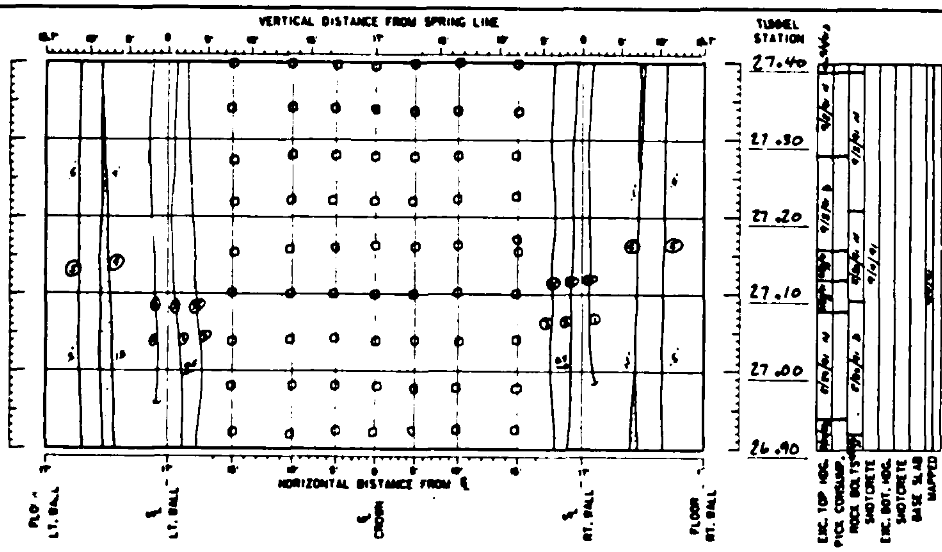
Geology By	
Drawn By	
Checked By	
Date	

US Army Corps of Engineers
HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 2

STATION 26.40 TO 26.90

SHEET 33 of 40



LEGEND

ROCK BOLT LOCATION	□
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2,3	Com bed	[illegible]	Ss. f. grn., gr. N4 W5 82, near horizontal, gtsme.
4,5	[illegible]	[illegible]	[illegible]

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
[illegible] bolt 87616

SCALE 1" = 10

Geology By	
Drawn By	
Checked By	
Date	

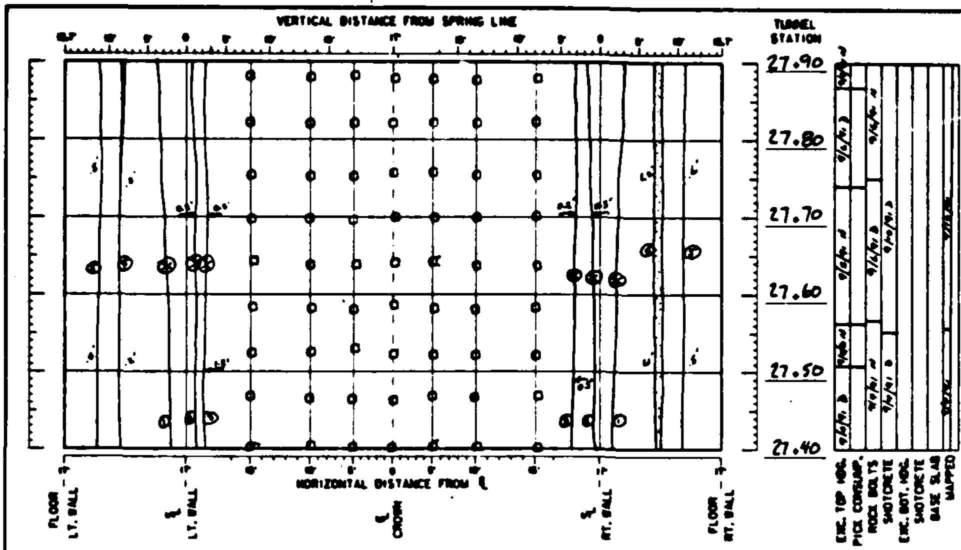
US Army Corps of Engineers
HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 2

STATION 26.90 TO 27.40

SHEET 34 of 40

PLATE D-44



LEGEND

ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ________.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2,3	[illegible]	[illegible]	Ss, f. gr., l gr. [illegible] horizontal [illegible]
4,5	Ss [illegible]	[illegible]	[illegible]

REMARKS: Tunnel Alignment - S 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers

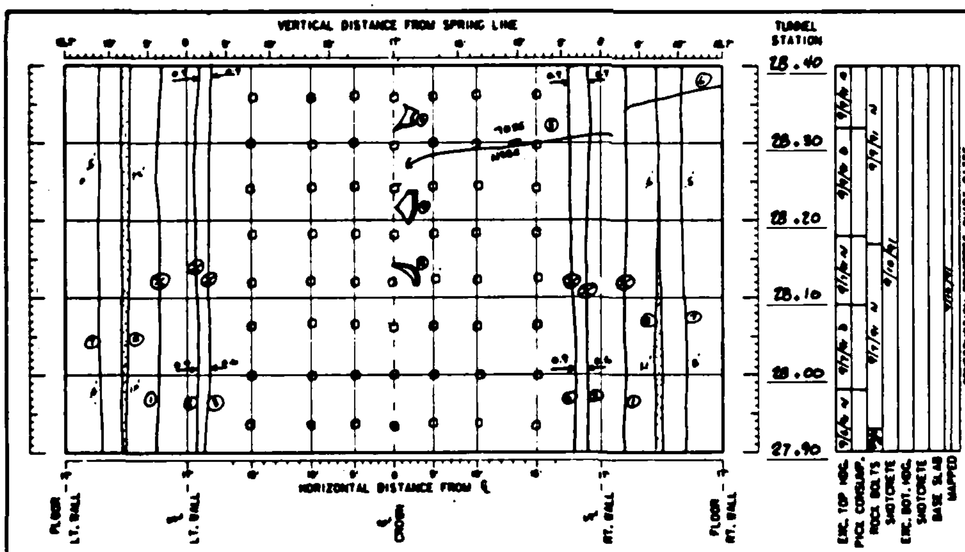
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2

STATION 27.40 TO 27.90

SHEET 35 OF 40

PLATE - 23



LEGEND

ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ________.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2,3	[illegible]	[illegible]	Ss, f. gr., l gr. [illegible] horizontal
4	Spalls	[illegible]	[illegible]
5	Joint	[illegible]	[illegible] N20E, 70 SE.
6	Joint	[illegible]	[illegible]
7,8	[illegible]	[illegible]	[illegible]

REMARKS: Tunnel Alignment - S 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

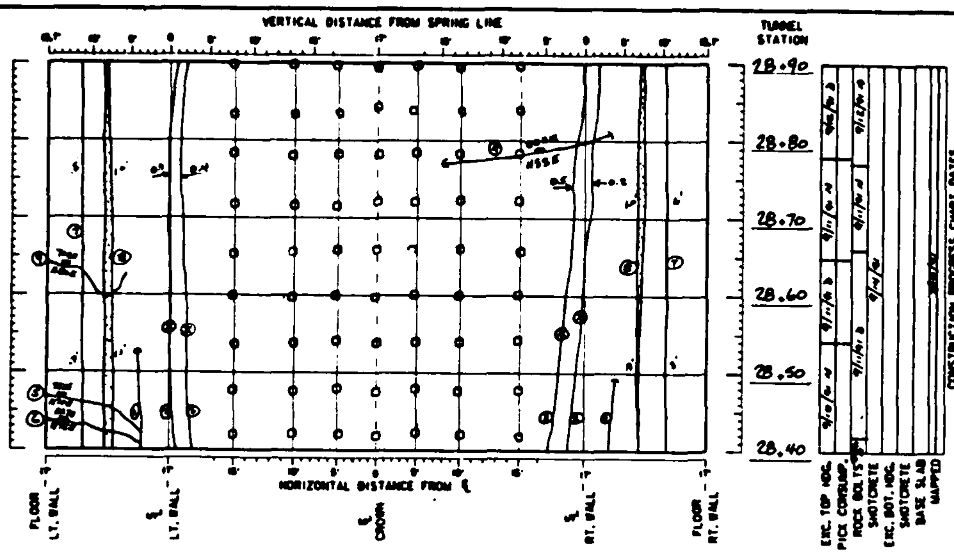
US Army Corps of Engineers

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2

STATION 27.90 TO 28.40

SHEET 36 OF 40



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ________.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2,3	Con. bed.	Tim Shy	Ss. f. grn., l gr., MH, W2, B2 plane, near horizontal
4	Fracture	Tim Shy	CB, U3, T2, R2, HL4, M4, N35E, 80SE
5	Jt	Ac	Jt N70E 75SE 0.1-.6 T6 R4 HL4 M2
7,8	Ss beds	Ac	Ss H4 W1 vf grn bed thickness indicated, steep ~ hor
6	Jt	Ac	Jt N75E 85SE op T6 W1 R5 HL4 ML
9	Jt	Ac	Irregular, op T6 R4 HL4, M2 N80E 75SE @ bottom

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

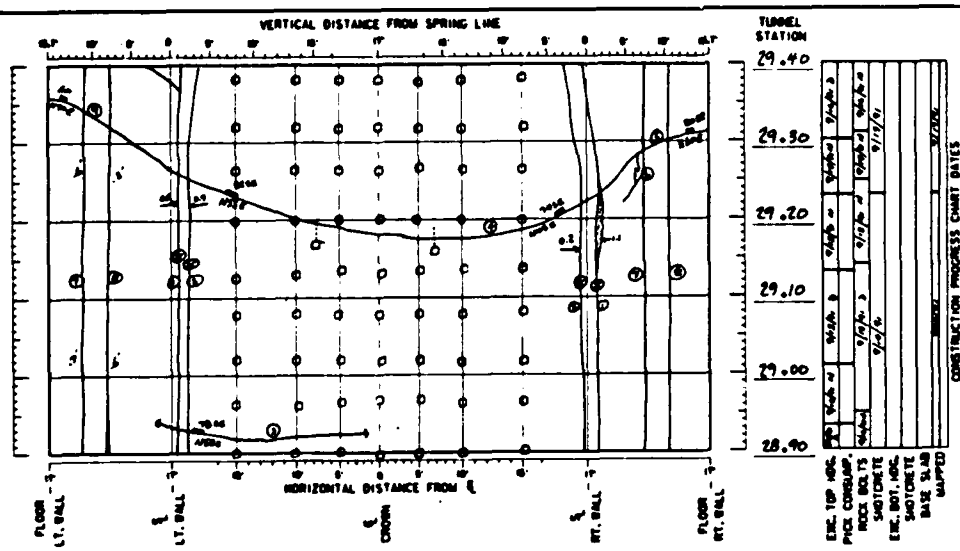
US Army Corps of Engineers

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2

STATION 28+40 TO 28+90

SHEET 37 OF 40



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ________.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	f grn bed	Tim Shy	Ss. f grn., l gr., H4, W1, Bplan plane, f grn. lam. near horizontal
3	Fracture	Tim Shy	CB, U3, T2, R2, HL4, M4, N80E 70SE
4	Fracture	Tim Shy	CB, U3, T2, R2, HL4, M4, N 80-85E, 79-82SE
7,8	Ss beds	Ac	Ss H4 W1 vf grn. thickness indicated, steep ~ hor
5	Jt	Ac	N60E 80SE op 0.1 T6 R4 HL4 W2 M2
6	Jt	Ac	N45W 85SW op T6 R5 HL4 M2
9	Jt	Ac	N80E, 80S op T6 R5 HL4 M2

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
9/5/91 - Set 4 rb, crown bolt at sta. 29+04, located approximately 11 ft. above crown.
9/19/91 - 2 @ 4m bolts added 29+18, angled 45° to support joint.

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

US Army Corps of Engineers

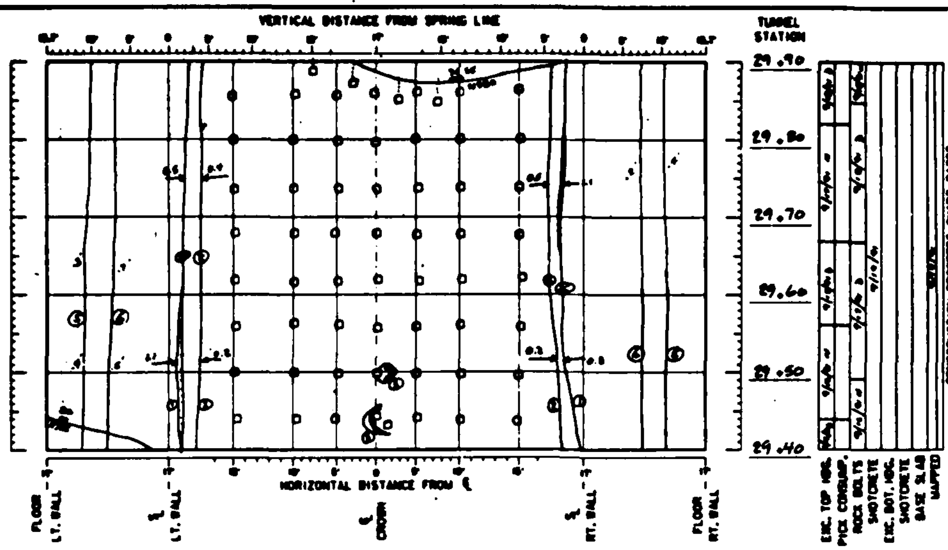
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 2

STATION 28+90 TO 29+40

SHEET 38 OF 40

PLATE D-46



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	C gra bed	Tim Sly	Sc. f gm. lor. H4 W5, near horizontal, [illegible]
3	Spalls	Tim Sly	<1 ft. [illegible] vertically
	Fractures	Tim Sly	C3, D4, T2, E2, M4, H4, N 58E, 70 SE
4	JC	[illegible]	JC N75E [illegible] SE 01-6 T2 R4 HL4 M2
5,6	[illegible]	[illegible]	Sc H4 W1, [illegible]

REMARKS: Tunnel Alignment - [illegible]
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
9/[illegible]/91 - Extra bolt 29+44 to secure crown spall
9/[illegible]/91 - 4 extra bolts added 29+88 to support fracture zone.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

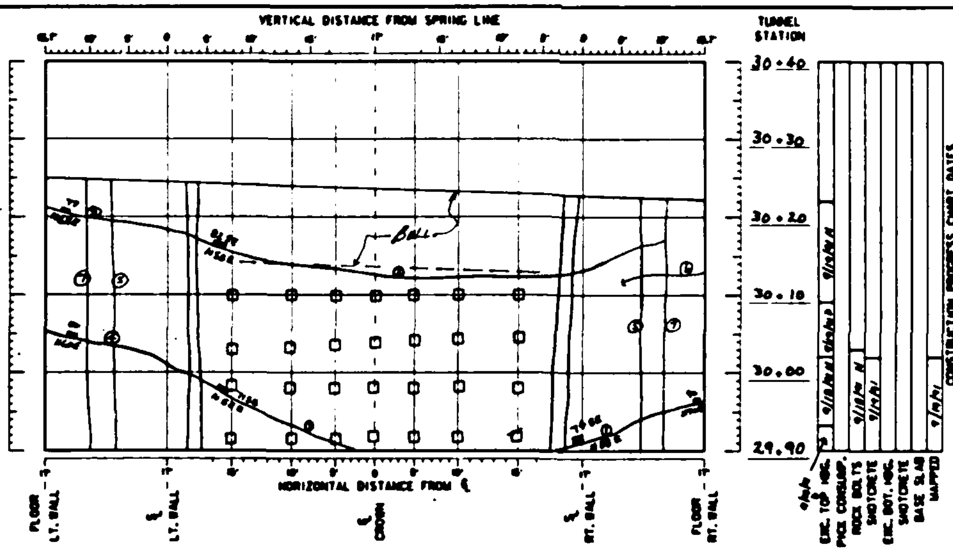
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 2

STATION 29+40 TO 29+90

SHEET 39 OF 40



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	JC	[illegible]	JC [illegible] 70-74 SE E2 [illegible] T2 [illegible] H4 [illegible]
2	JC	[illegible]	JC N56E [illegible]
4	JC	[illegible]	[illegible] R5 HL4 M2
3	JC	[illegible]	JC N65E 77SE [illegible] T2 [illegible] R5 HL4 M2
6	JC	[illegible]	JC N70E 83 SE C2 and T2 R4 HL4 M2
5,7	Sc bed	[illegible]	[illegible]

REMARKS: Tunnel Alignment - [illegible]
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

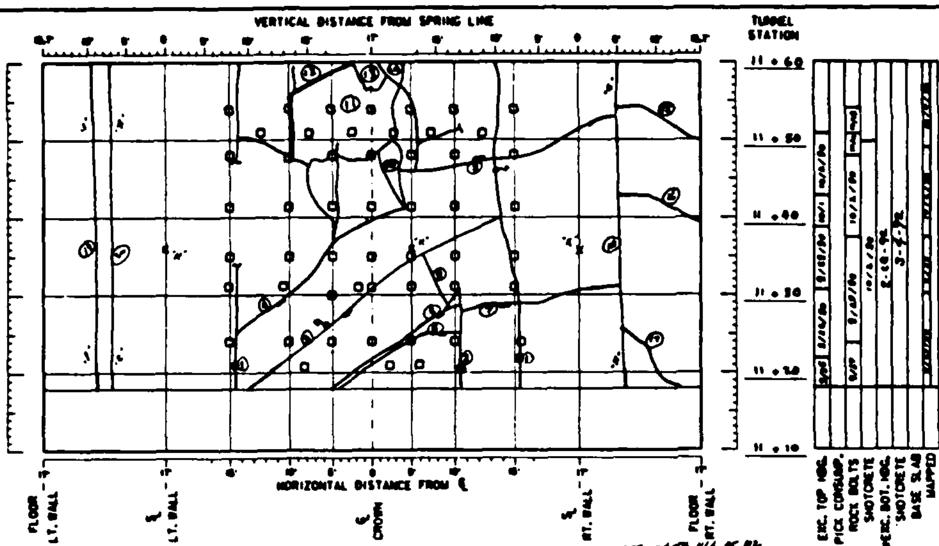
TUNNEL T- 2

STATION 29+90 TO 30+40

SHEET 40 OF 40

PLATE D-47

VERTICAL DISTANCE FROM SPRING LINE



LEGEND

ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION	
1, 2	Bdd pln	[illegible]	C?, 00, T0-1 (6-?), HL4, R5, M2	Nearly horizontal
3	Jt		C, 00, T0-1 (?-?), HL4, R4, M5	N10W, 80SW
4	Jt		C, 00, T0-1 (?-?), HL4, R4, M2	N03W, 70SW
5, 6	Jts		C, 00, T0-1 (?-?), HL4, R4, M2	N10W, 80SW
7	Jt		C, 00-1, T0, HL4, R4, M2	N03W, 73SW
8	Jt	[illegible]	C2, 01, T1, HL4, R4, M2	
9			C2, 04, T1, HL4, R2, M4	N08E, 67SE
10	Fallout		[illegible] bounded by N78W, 56SW & N10E, 25SE	
11	Fallout		10'x10'x0.8' fallout to bdd pln approx 0.8' above crown	
12	Frac		Thick on left side. Mapped bdd on these edges	N18E 65SE
13	Fallout		1' [illegible] breakage	
14	Frac		N77W, 84NE Bounds fallout	

14 N48, 75SE, 00, T0, HL4, R5, M2
15 N8E, 75SE
16 N5W, 75SW

15, 17, 18 Sh lab. bl. & gyn. lt gry. thickness indicated on bm

REMARKS: Tunnel alignment - S 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
9/23/80 - TX anchor installed @ 11+28
10/2/80 - TX anchors installed, removed [illegible] installed @ 11+27. TX anchors abandoned @ T28, T29, T30
10/13/80 6 anchor bolts installed @ sta. 11+5?
8/10/81 Bottom heading exc. w/ [illegible] to [illegible]
8/11/81 Begin blasting bottom heading.
* "Exc. Bot. Hdg." is date of trimming w/ roadheader.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers

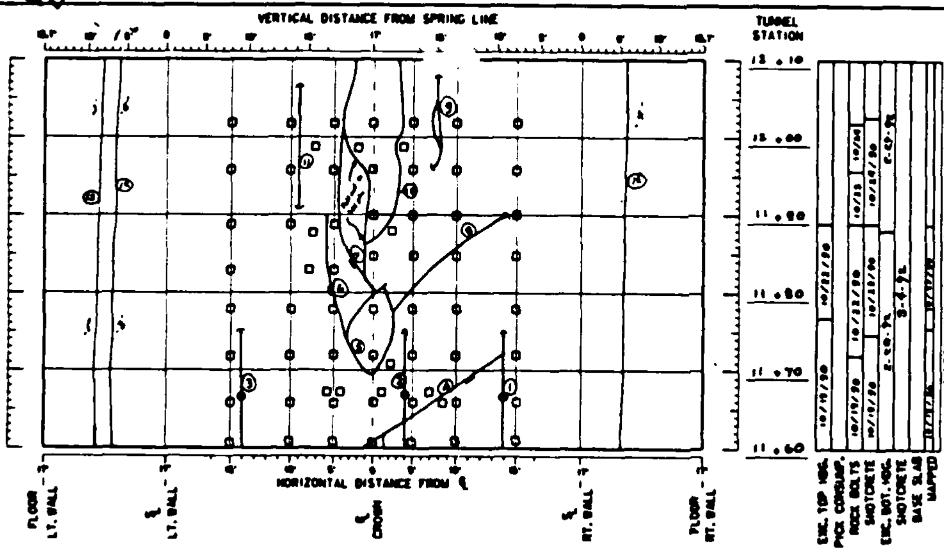
HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 3

STATION 11 + 10 TO 11 + 60

SHEET 1 OF 31

VERTICAL DISTANCE FROM SPRING LINE



LEGEND

ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-1.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION	
1	Bdd pln	[illegible]	C4-5, 00, T0, HL4, R5, M1	Nearly horizontal
2	Bdd pln		C4-5, 00, T0, HL4, R5, M1	Nearly horizontal
3	Bdd pln		C4-5, 00, T0, HL4, R5, M1	Nearly horizontal
4	Jt		C3, 00-1, T0, R4	N15E, 80NW
5	Bdd pln		Roof fallout to nearly horizontal bdd pln, R5 (2-1.0' above crown)	
6	Bdd pln	[illegible]	C3, 02, T2, HL4, R5, M2	Dip = 75° NE
7	Bdd pln		C3, 02, T2, HL4, R5, M2	Dip = 75° NE
8	Jt		C3, 02, T2, HL4, R5, M2	Nearly Vertical
9	Bdd pln	[illegible]	SP1, C3, 00	Possible fallout
10	Bdd pln	[illegible]	00, T0, HL4, R5, M1	
11	Bdd pln	[illegible]	00, T0, HL4, R5, M1	May be same as feature No. 2
12, 13	Sh lab	[illegible]	Sh lab. bl. & gyn. lt gy. thickness indicated	

REMARKS: Tunnel alignment - S 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
10/19/80 [illegible] 1" layer to sta. 11+75
8/10/81 Bottom heading exc. w/ [illegible] to 11+81
8/11/81 Begin blasting bottom heading.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers

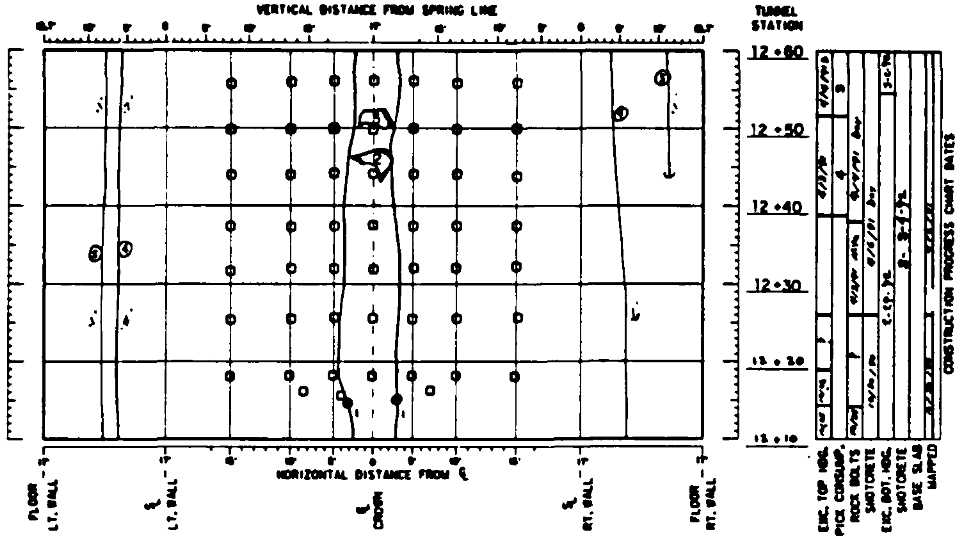
HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 3

STATION 11 + 60 TO 12 + 10

SHEET 2 OF 31

PLATE D-48



LEGEND

ROCK BOLT LOCATION
SPBM LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-3 thru T3-3

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd pln	[illegible]	[illegible]
2,3	[illegible]	[illegible]	[illegible]
4,5	[illegible]	[illegible]	[illegible]

REMARKS: Tunnel Alignment - [illegible]
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

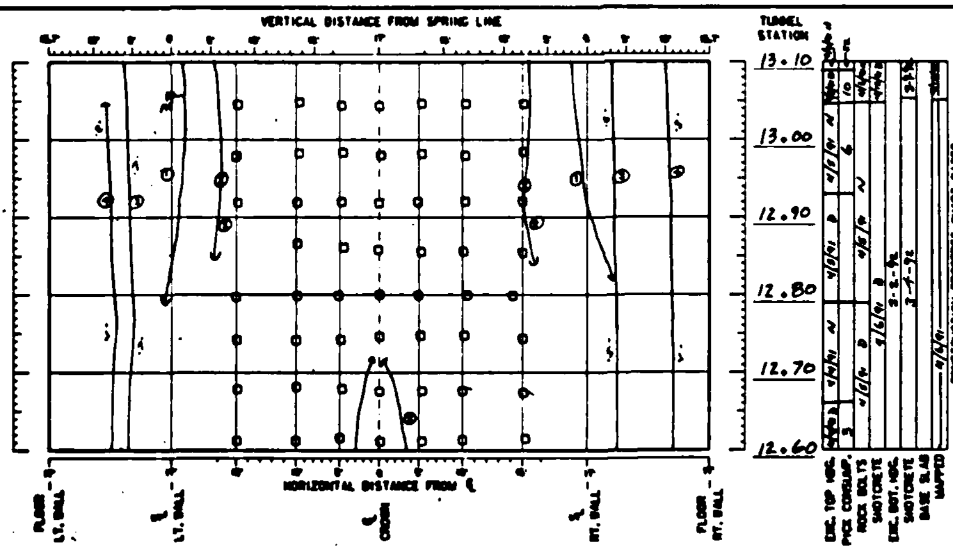
US Army Corps of Engineers

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 3

STATION 12+10 TO 12+60

SHEET 3 OF 31



LEGEND

ROCK BOLT LOCATION
SPBM LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-3 and T3-4

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdg pln	TJ	[illegible] Lgr, slight NE dip.
2	Bdg pln	TJ	[illegible] Lgr, near horizontal
3,4	[illegible]	[illegible]	[illegible]

REMARKS: Tunnel Alignment - [illegible]
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

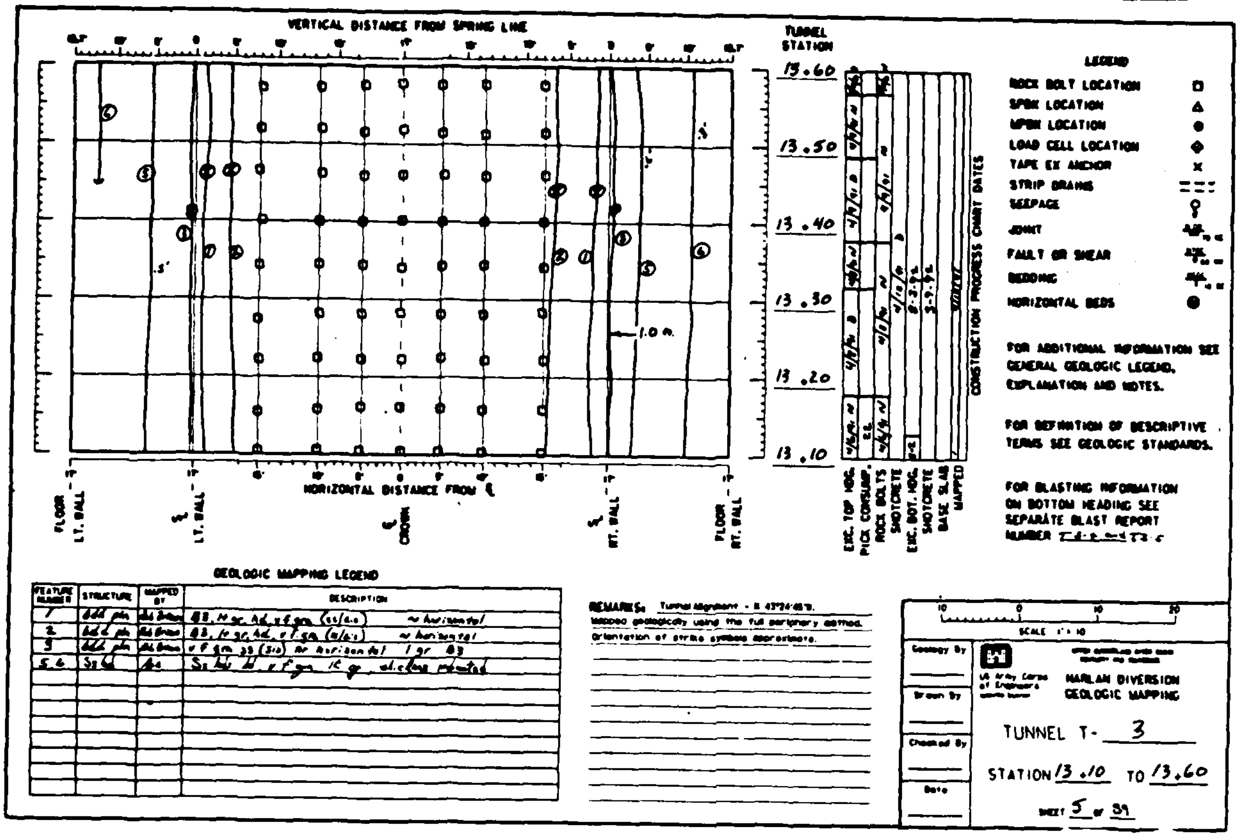
US Army Corps of Engineers

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 3

STATION 12.60 TO 13.10

SHEET 4 OF 31


VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
13+60
13+50
13+40
13+30
13+20
13+10
HORIZONTAL DISTANCE FROM ℄
FLOOR - LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR - RT. WALL
EXC. TOP HDG.
PICK CONSLID.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
SCALE 1" = 10'
Geology By
Drawn By
Checked By
Date
US Army Corps of Engineers
MARLAN DIVERSION GEOLOGIC MAPPING
TUNNEL T- 3
STATION 13+10 TO 13+60
SHEET 5 OF 39

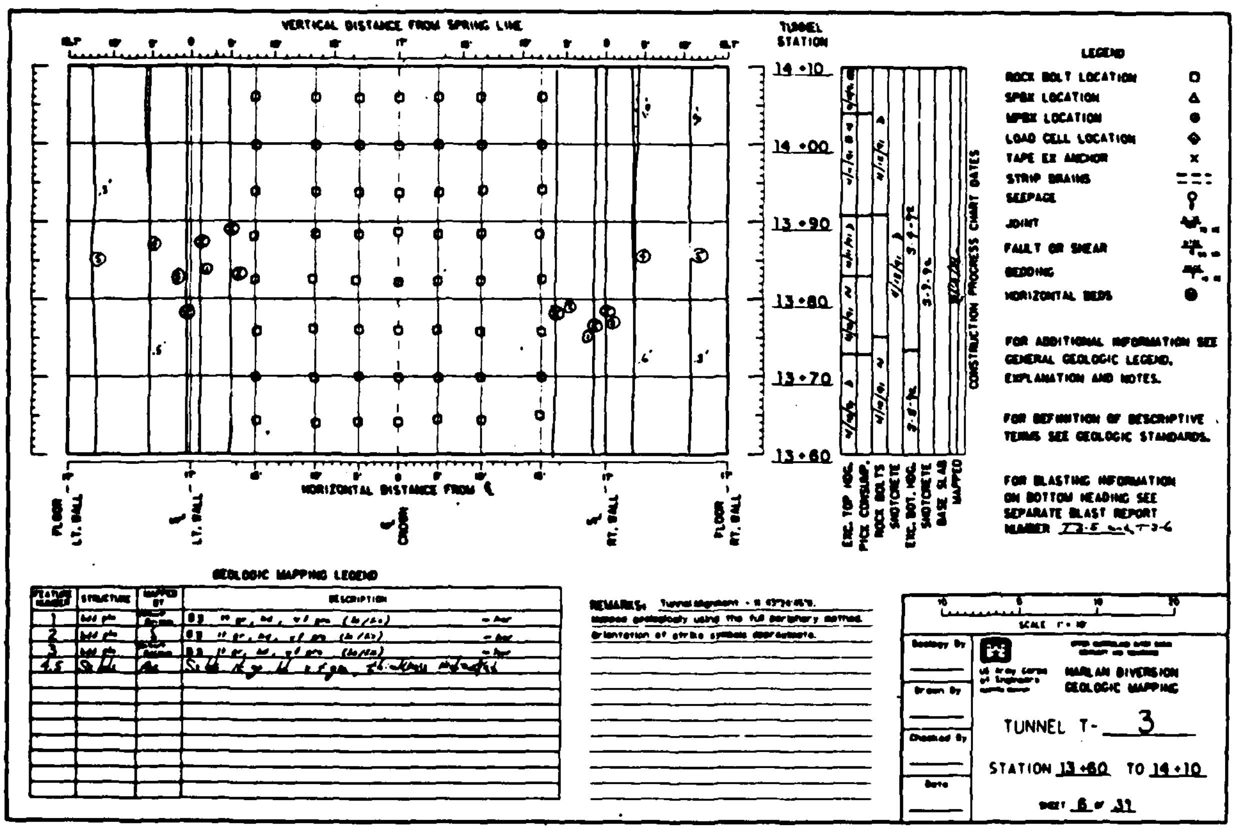
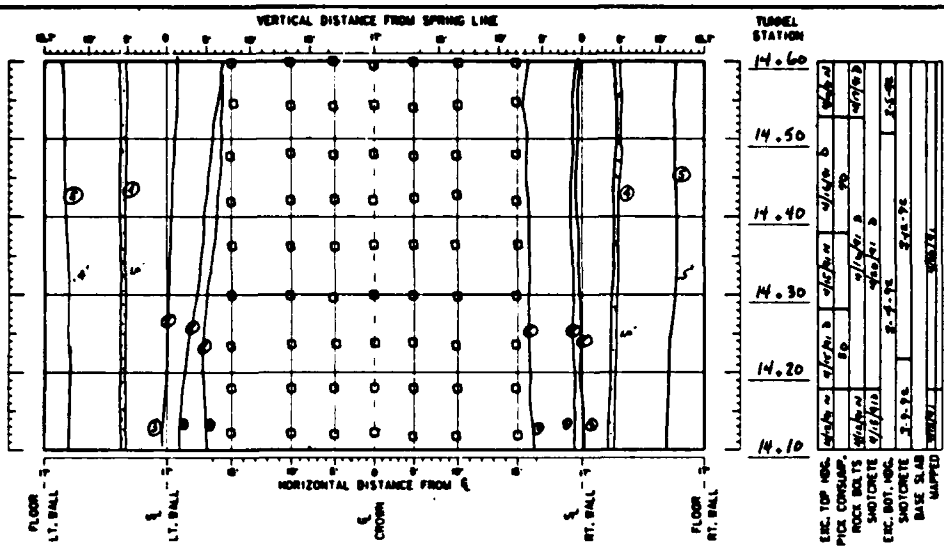

VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
14+10
14+00
13+90
13+80
13+70
13+60
HORIZONTAL DISTANCE FROM ℄
FLOOR - LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR - RT. WALL
EXC. TOP HDG.
PICK CONSLID.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
SCALE 1" = 10'
Geology By
Drawn By
Checked By
Date
US Army Corps of Engineers
MARLAN DIVERSION GEOLOGIC MAPPING
TUNNEL T- 3
STATION 13+60 TO 14+10
SHEET 6 OF 39

PLATE D-50



LEGEND

ROCK BOLT LOCATION	□
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-6 and T3-7

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd pln	[illegible]	SS, lt gr, hd, v.f. grn. [illegible] ~ horiz.
2	Bdd pln	"	SS, lt gr, hd, v.f grn. [illegible] ~ horiz.
3	Bdd pln	[illegible]	SS, lt gr, hd, v.f grn. [illegible] ~ hor.
4,5	Sh [illegible]	[illegible]	S. lt gr, hd, v.f grn. thickness indicated

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
* Feature 3 not fully [illegible] as of 4/20/91

SCALE 1" = 10'

US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

Geology By

Drawn By

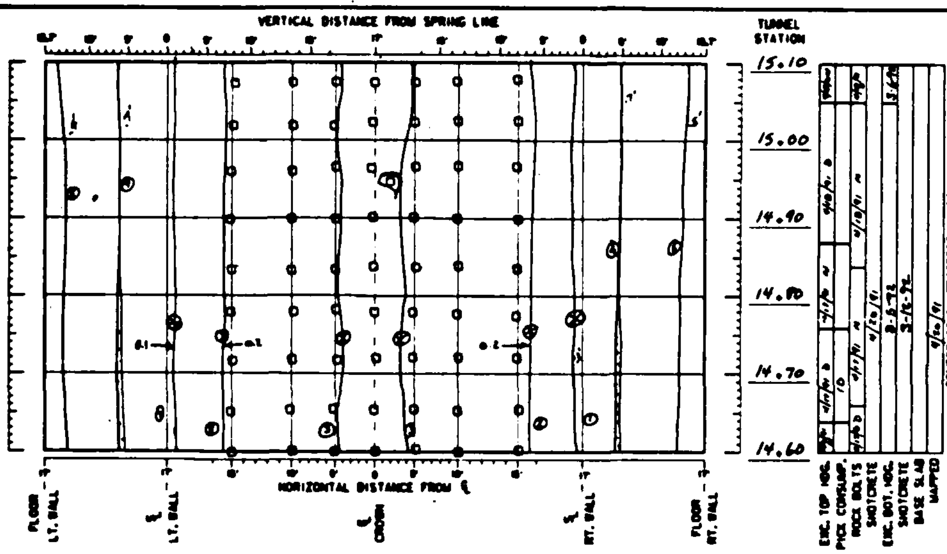
Checked By

Date

TUNNEL T- 3

STATION 14.10 TO 14.60

SHEET 7 of 39



LEGEND

ROCK BOLT LOCATION	□
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-7 and T3-8

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdg Pln	[illegible]	SS lgy, glauc, fine grn, Ss, nr. horizontal
2	Bdg Pln	"	SS lgy, glauc, fine grn, Ss, nr. horizontal
3	Bdg Pln	[illegible]	SS lgy, glauc, fine grn, Ss, nr. horizontal
4	Bd pln	[illegible]	[illegible]
6	Bd pln	[illegible]	Ss " " " " thickness indicated

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
• Extra bolt [illegible] to secure [illegible] edge of bedding plane

SCALE 1" = 10'

US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

Geology By

Drawn By

Checked By

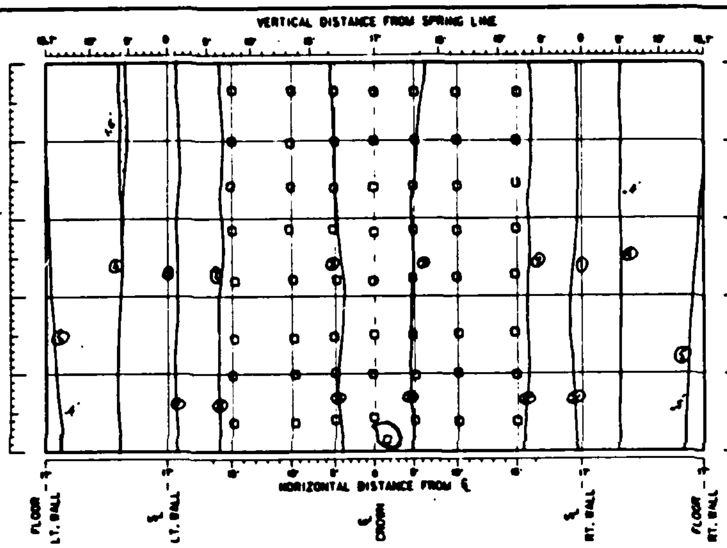
Date

TUNNEL T- 3

STATION 14.60 TO 15.10

SHEET 8 of 39

PLATE D-51



CONSTRUCTION PROGRESS CHART DATES

EXC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED

3-6-92
3-12-92

LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-9 and T3-10

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd. pln	[illegible]	83, 1 gm, planar, near horizontal
2	Bdd. pln	[illegible]	83, 1 gm, planar, near horizontal
3	Bdd. pln	[illegible]	83, 1 gm, planar, near horizontal
4,5	Sh. bd	[illegible]	[illegible]

REMARKS: Tunnel Alignment - [illegible]
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
[illegible] - [illegible] bolt, [illegible] 15+12 to secure [illegible] edge of crown.

SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

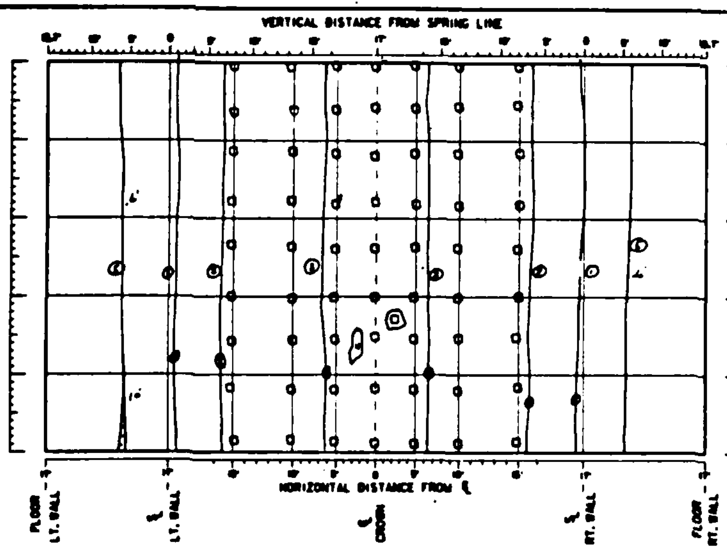
US Army Corps of Engineers

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 3

STATION 15+10 TO 15+60

SHEET 9 OF 39



CONSTRUCTION PROGRESS CHART DATES

EXC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED

3-7-92
3-12-92

LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-10 and T3-11

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd. pln	[illegible]	83, [illegible] (m). Approximately horizontal
2	Bdd. pln	[illegible]	43, [illegible] (m). Near horizontal
3	Bdd. pln	[illegible]	43, [illegible] (m). Near horizontal
4	[illegible]	[illegible]	[illegible]
5	Sh. bd	[illegible]	[illegible]

REMARKS: Tunnel Alignment - [illegible]
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers

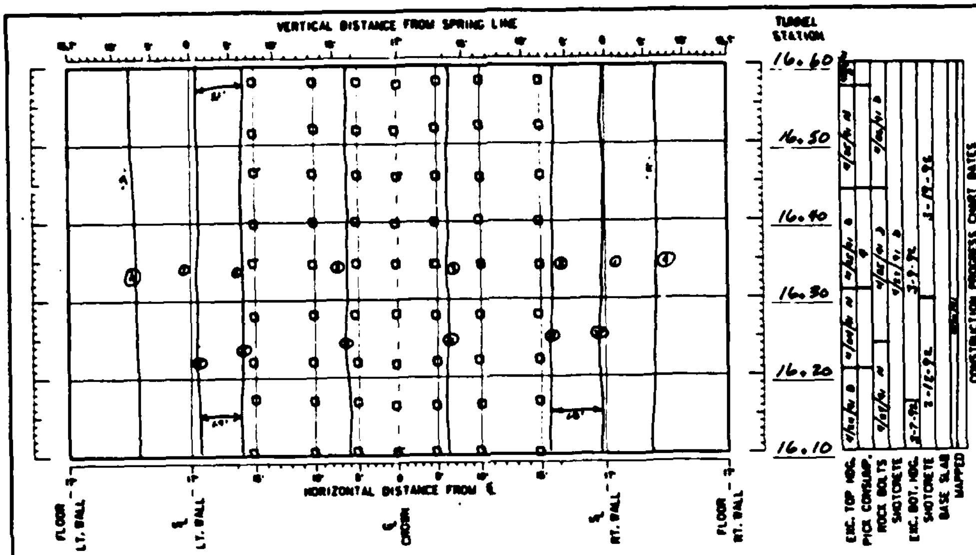
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 3

STATION 15+60 TO 16+10

SHEET 10 OF 39

PLATE D-52



LEGEND

ROCK BOLT LOCATION	□
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-11 and T3-12

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd pln	[illegible]	SS, lt gr, bd, f-v.f. gn (ss) near horizontal
2	Bdd pln	〃	SS, lt gr, bd, v f gn (ss), near horizontal
3	Bdd pln	[illegible]	SS, lt gr, bd, v f gn (ss), near horizontal
4	[illegible]	[illegible]	[illegible]

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full peripheral method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

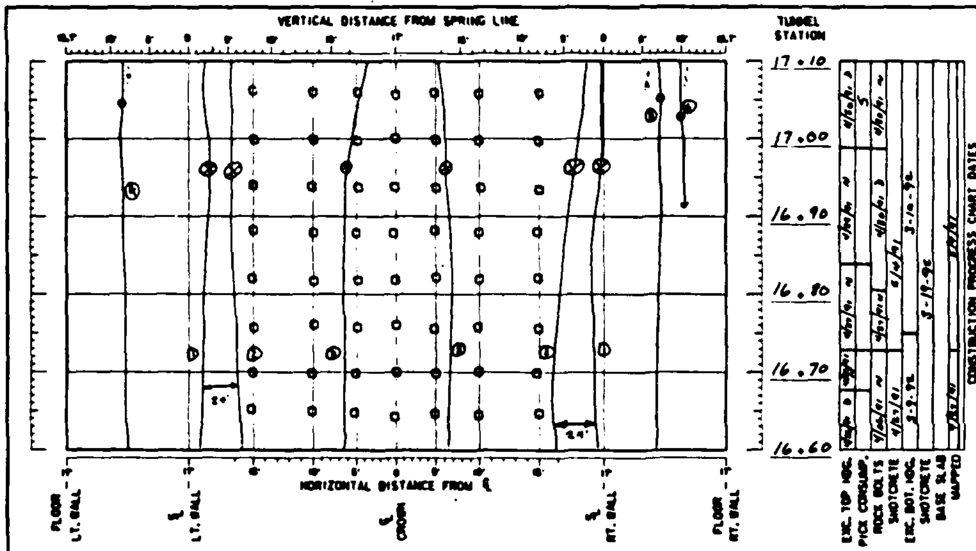
US Army Corps of Engineers

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 3

STATION 16+10 TO 16+60

SHEET 11 of 39



LEGEND

ROCK BOLT LOCATION	□
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-12 and T3-13

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd pln	[illegible]	SS, lt gr, bd, v f gn, near horizontal
2	Bdd pln	〃	SS, lt gr, bd, v f gn, near horizontal
3	Bdd pln	[illegible]	SS, lt gr, bd, v f gn, near horizontal
4	Bdd Pln	[illegible]	[illegible]
5	Bdd Pln	[illegible]	[illegible]

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full peripheral method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers

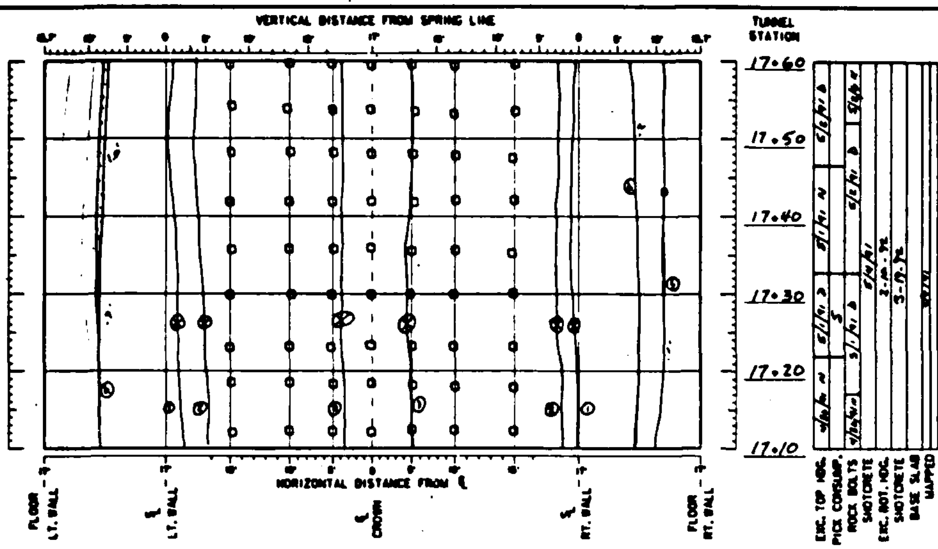
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 3

STATION 16+60 TO 17+10

SHEET 12 of 39

PLATE D-53



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-13 and T3-14

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdg Pln	[illegible]	B4, l gry, [illegible] Ss beds, Near horizontal, f grn.
2	Bdg Pln	[illegible]	B3, l gry [illegible] Sslts, Near horizontal, f grn.
3	Bdg Pln	[illegible]	B4, l gry, [illegible] Ss beds, Near horizontal, f grn.
4	Bdd Pln	PAR	B4, lt gry, bd, v.f grn, ss, near hor, [illegible]
5	Bdd Pln	PAR	B2, lt gry, bd, v.f grn, ss, near hor, [illegible]

REMARKS: Tunnel alignment - N 47°24'45"E. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

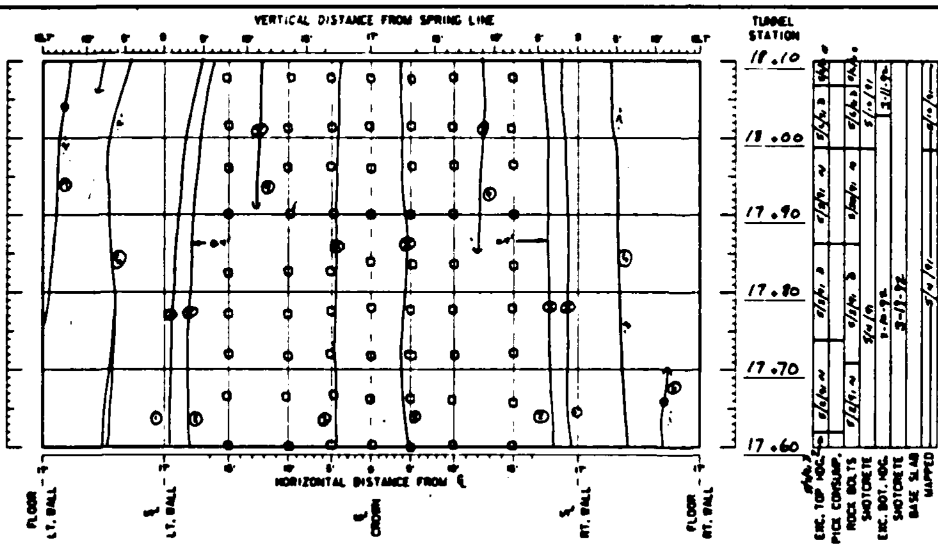
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 3

STATION 17+10 TO 17+60

SHEET 13 of 39



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-14 and T3-15.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdg Pln	[illegible]	B4 l gry, [illegible] Slt bdd, Near horizontal
2	Bdg Pln	/	B3, l gry [illegible] beds, [illegible]
3	Bdg Pln	/	B4 l gry, [illegible] beds, [illegible] Near horizontal
4	Bdg Pln	[illegible]	B4 l gry, f grn Ss [illegible] Near horizontal.
5,6,7	Bdd Pln	PAR	B2, lt gry, bd, v.f grn, ss, near hor, [illegible]

REMARKS: Tunnel alignment - N 47°24'45"E. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.
[illegible] - Air quality [illegible] - ventilation lagging [illegible] at 18+15 (885 ft.)

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

US Army Corps of Engineers

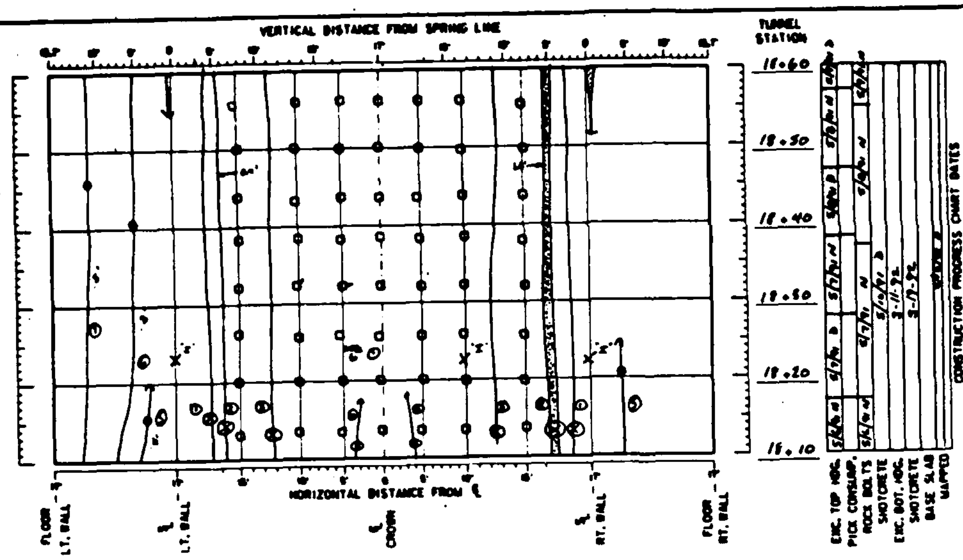
HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 3

STATION 17+60 TO 18+10

SHEET 14 of 39

PLATE D-54



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-15 and T3-16

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdg Pln	Tim Sky	B4, l gry, fine grn, laminated Ss, near horizontal
2	Bdg Pln	Tim Sky	B3, l gry, fine grn, grnw laminae, near horizontal
3	Bdg Pln	Tim Sky	B4, l gry, fine grn, lams, near horizontal
4	Bdg Pln	Tim Sky	B4 l gry, near horizontal
5,6,7	Bed Plns	PAE	B3/B4, lt gry, bd, v.f grn, Ss, near hor, thickness indicated.

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full peripheral method.
Orientation of strike symbols approximate.
3/1/91 - Array "S" Tx installed sta 18+25 beneath MPBX-6.

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

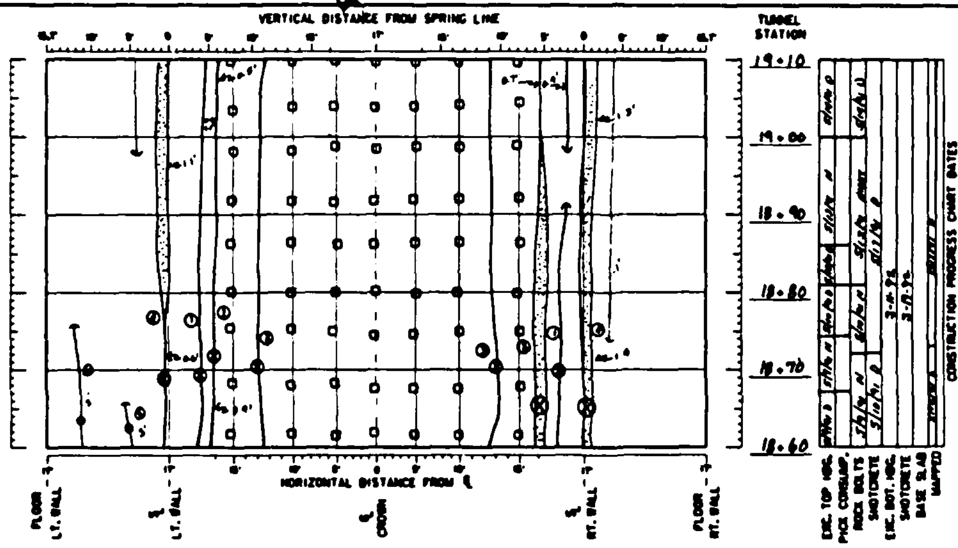
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 3

STATION 18+10 TO 18+60

SHEET 15 of 39



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-16 and T3-17

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd pln	T.Sky	Near horizontal, lt gr, F.grn, laminated, B4
2	Bdd pln	T.Sky	Near horizontal lt gr, F.grn, B3
3	Bdd pln	T.Sky	Near horizontal lt gr, B4
4	Ss bdd	[illegible]	Near horizontal, lt gr, F.grn, Ht, B3
5,6	Bdd Pln	PAE	B3 lt gry, bd, v.F.grn, Ss, near horizontal, thickness indicated

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full peripheral method.
Orientation of strike symbols approximate.
Slab: Replaced cracking bolt 18+80

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

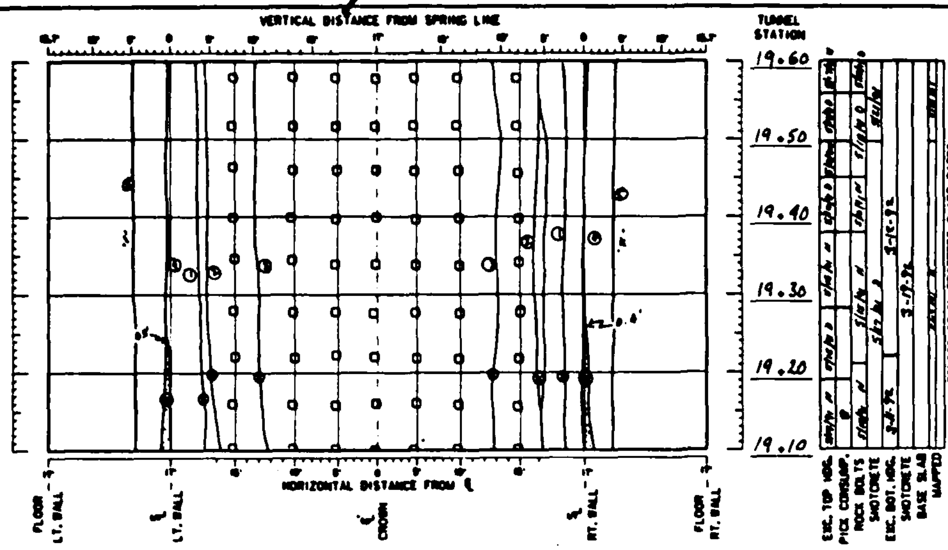
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 3

STATION 18+60 TO 19+10

SHEET 16 of 39



LEGEND

ROCK BOLT LOCATION	◻
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd.	[illegible]	Near horizontal, lt. gr., F. gra., laminated, H5, B4
2	Bdd.	[illegible]	Near horizontal, lt. gr., F. gra., H5, B3
3	Bdd.	[illegible]	Near horizontal, lt. gr., F. gra., H5, B4
4	Ss. bd.	[illegible]	Near horizontal, lt. gr., F. gra., H5, B3
5	Ss.	[illegible]	[illegible]

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By	
Drawn By	
Checked By	
Date	

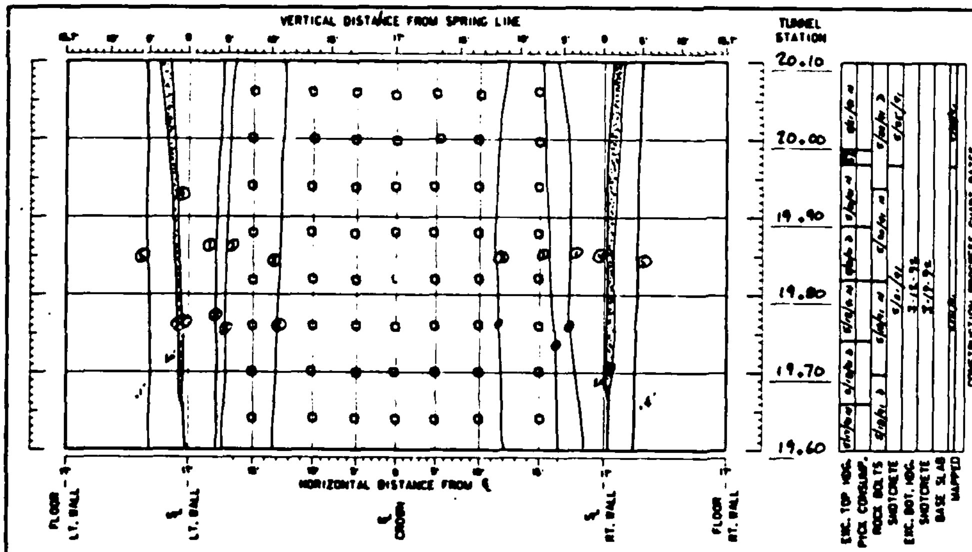
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 3

STATION 19+10 TO 19+60

SHEET 17 OF 39



LEGEND

ROCK BOLT LOCATION	◻
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER 73-13 and 73-14

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	ss bd.	[illegible]	ss bed, 0.5 ft. thick, H4, horizontal [illegible]
2	ss bd.	[illegible]	ss bed, 0.4 ft. thick, [illegible], H4, horizontal
3	ss bd.	[illegible]	ss bed, 0.1-0.3 ft. thick, H4, horizontal
4	ss bd.	[illegible]	ss bed, 0.9 ft., H4, horizontal
5	Ss bd.	[illegible]	[illegible]

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By	
Drawn By	
Checked By	
Date	

US Army Corps of Engineers

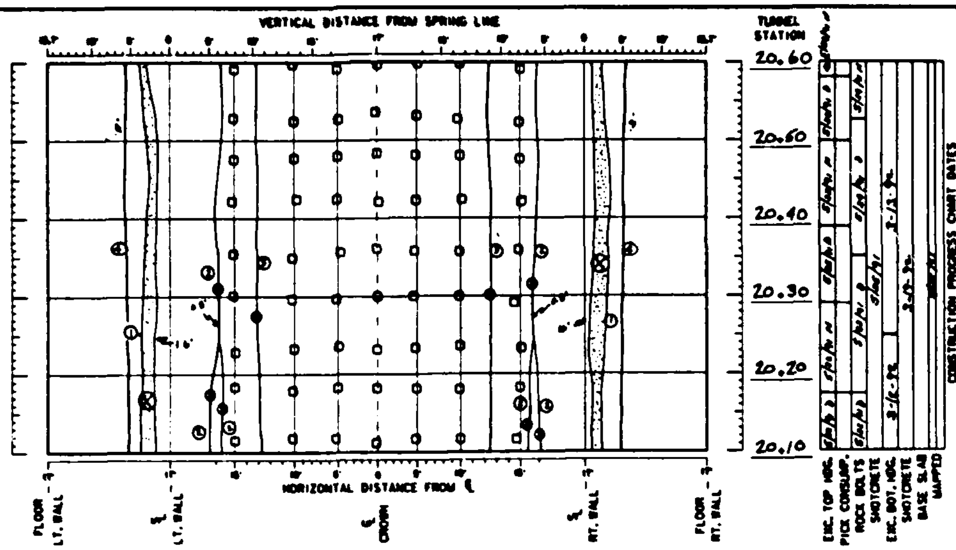
HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 3

STATION 19+60 TO 20+10

SHEET 18 OF 39

PLATE D-56



LEGEND

ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-20 and T3-21

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Add. pln.	T.SHY	Ss, near horizontal, lt gr, F grn, glass, B3
2	Add. pln.	T.SHY	Ss, near horizontal, lt gr, F grn, glass, laminated, B2
3	Add. pln.	T.SHY	Near horizontal, lt. gr., F grn, B4
4	Ss [illegible]	[illegible]	[illegible]

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
5/25/91 - Oil slops in tunnel from face back to 20+20. Flame at 19+00.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

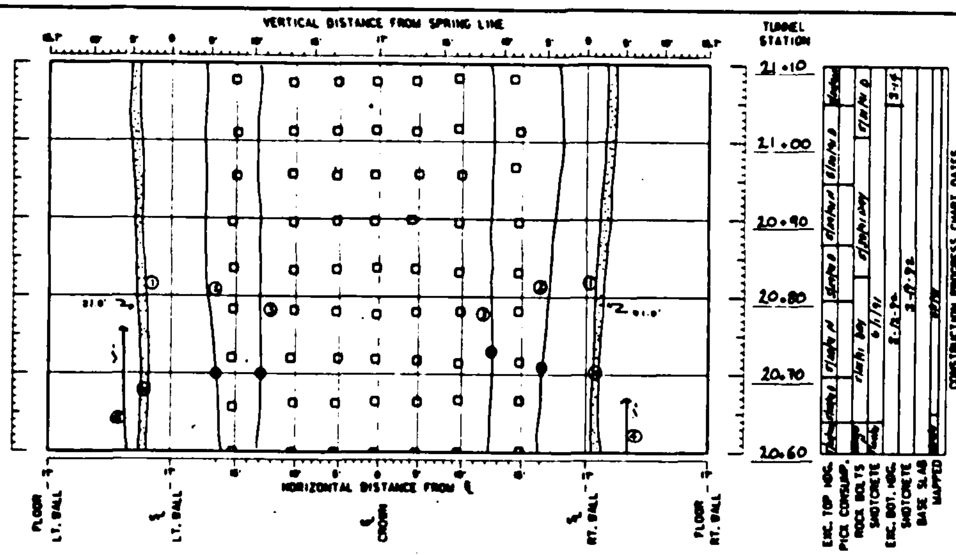
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 3

STATION 20+10 TO 20+60

SHEET 19 OF 39



LEGEND

ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-21 AND T3-22

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Add. Pln.	T.SHY	Near horizontal, lt gr, F grn, glass, B3
2	Add. pln.	T.SHY	Near horizontal, lt gr, F grn, glass, [illegible], B2
3	Add. pln.	T.SHY	Near horizontal, lt gr, F grn, B4
4	[illegible]	[illegible]	[illegible]

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers

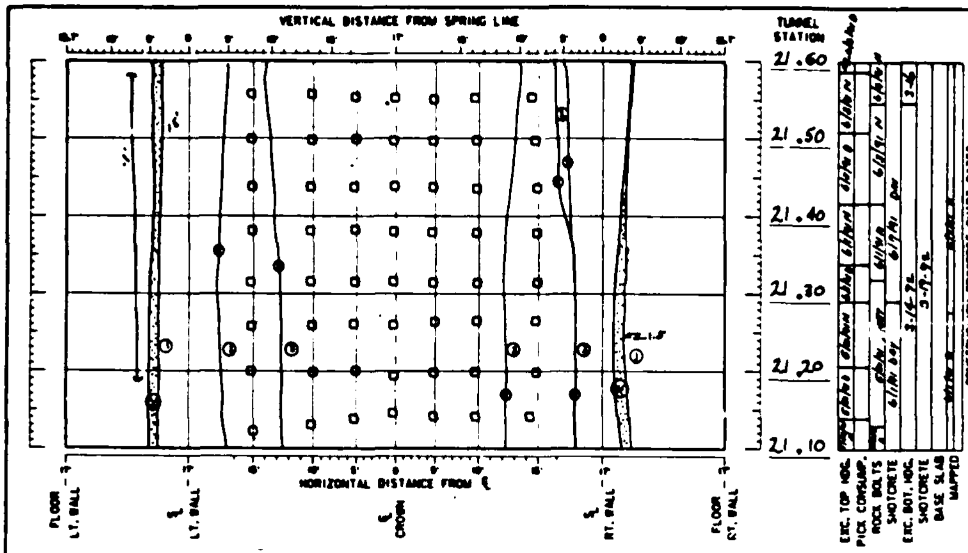
HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 3

STATION 20+60 TO 21+10

SHEET 20 OF 39

PLATE D-57



LEGEND

ROCK BOLT LOCATION	□
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	☰
SEEPAGE	♀
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER *T3-22 and T3-23*

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd. pln.	T.Sny	Ss, near horizontal, lt.gr., f.grn, qtzose, H4, B3
2	Bdd. pln.	T.Sny	Ss, near horizontal, lt.gr., f.grn, qtzose, H4, B3, splits into two horizons in right wall
3	Bdd. pln.	T.Sny	Near horizontal, lt.gr., B4.

REMARKS: Tunnel alignment - N 43°24'45"E. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.
6/2/81 - Bdd pln feature ① below, exposed from 26 past 21+11

SCALE 1" = 10'

US Army Corps of Engineers

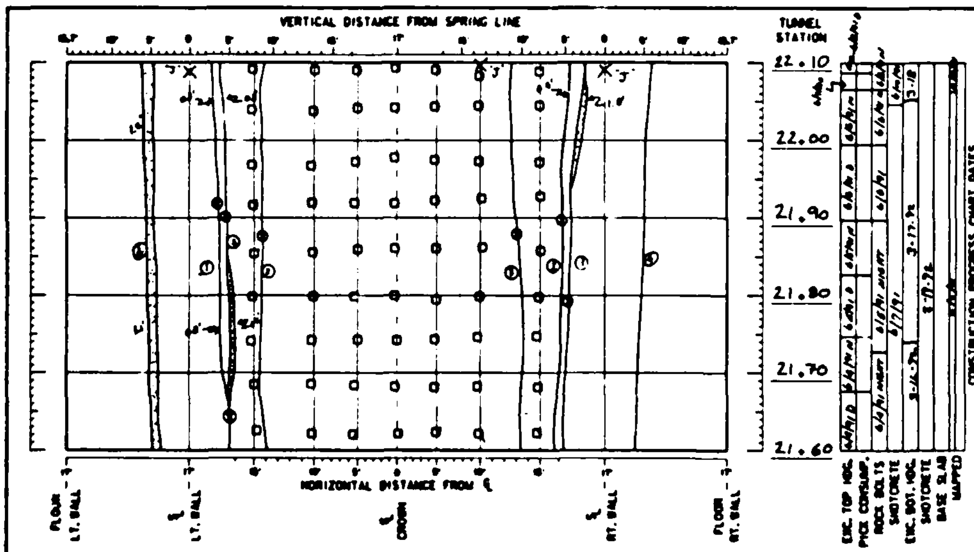
HARLAN DIVERSION GEOLOGIC MAPPING

Geology By	
Drawn By	
Checked By	
Date	

TUNNEL T- *3*

STATION *21+10* TO *21+60*

SHEET *21* of *31*



LEGEND

ROCK BOLT LOCATION	□
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	☰
SEEPAGE	♀
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER *T3-23 and T3-24*

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd. pln.	T.Sny	Ss, near horizontal, lt.gr., f.grn, qtzose, H4, B3.
2	Bdd. pln.	T.Sny	Ss, near horizontal, lt.gr., f.grn, qtzose, H4, B3
3	Bdd. pln.	T.Sny	Near horizontal, lt.gr., B4.
4	Sh. bd.	[illegible]	Ss, v.f.grn, bd lt. gr. [illegible]

REMARKS: Tunnel alignment - N 43°24'45"E. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.
6/8/81 - TX anchor "J" installed 22+09 location below MPBX-8.

SCALE 1" = 10'

US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

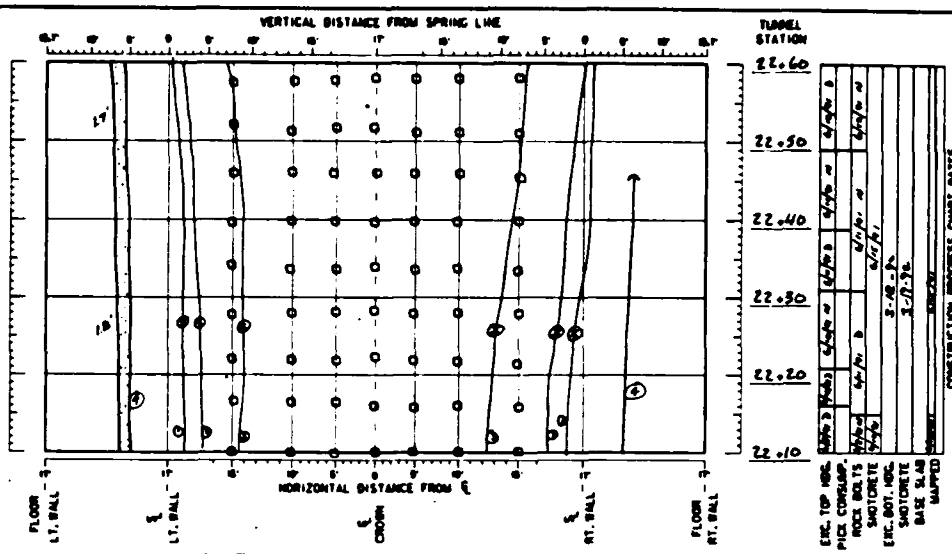
Geology By	
Drawn By	
Checked By	
Date	

TUNNEL T- *3*

STATION *21+60* TO *22+10*

SHEET *22* of *31*

PLATE D-58



LEGEND

ROCK BOLT LOCATION	◻
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-29 and T3-65.

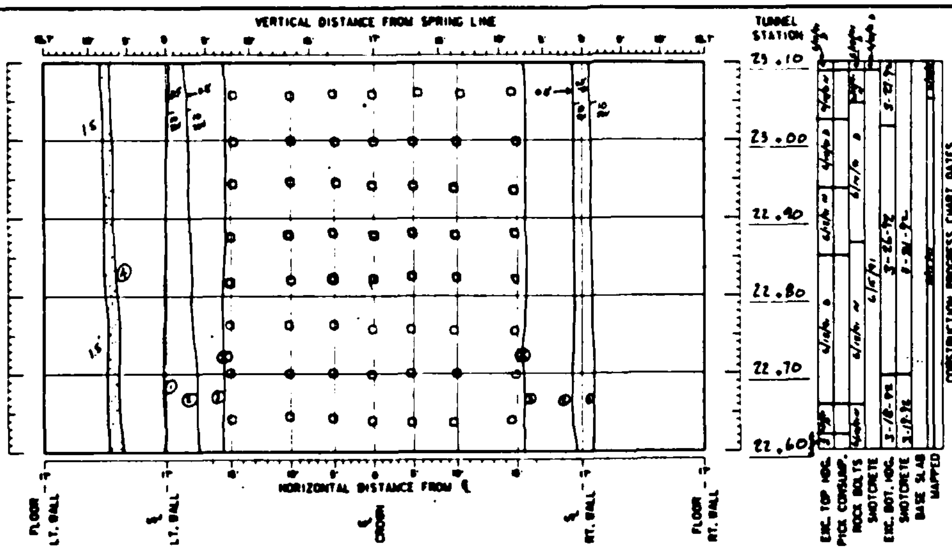
GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bed	[illegible]	88, l gry, [illegible], fine gr., [illegible] Ss, near horizontal
2	Bed	[illegible]	88, l gry, [illegible], fine gr., [illegible] Ss, near horizontal
3	[illegible]	[illegible]	84, l gry, near horizontal
4	[illegible]	[illegible]	[illegible]

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
6/6/91 - 0.1 on floor: 22+15 → 22+80

SCALE 1" = 10'

Geology By	US Army Corps of Engineers — HARLAN DIVERSION GEOLOGIC MAPPING
Drawn By	TUNNEL T- 3
Checked By	STATION 22+10 TO 22+60
Date	SHEET 23 OF 39



LEGEND

ROCK BOLT LOCATION	◻
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

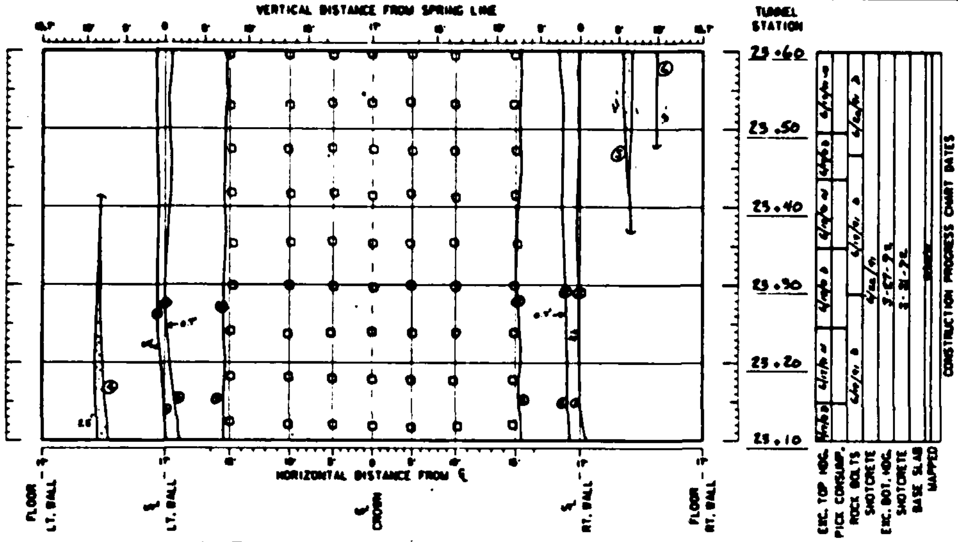
GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bed	[illegible]	88, Ss, l gry, [illegible], fine gr., dips 10° [illegible]
2	Bed	[illegible]	83, Ss, l gry, [illegible], fine gr., shale laminations, dip 10° [illegible]
3	[illegible]	[illegible]	84, l gry, near horizontal
4	[illegible]	[illegible]	[illegible]

REMARKS: Tunnel Alignment - N 43°24'45"E
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
6/6/91 - 0.1 on tunnel floor 22+15 to 22+75

SCALE 1" = 10'

Geology By	US Army Corps of Engineers — HARLAN DIVERSION GEOLOGIC MAPPING
Drawn By	TUNNEL T- 3
Checked By	STATION 22+60 TO 23+10
Date	SHEET 24 OF 39



LEGEND

ROCK BOLT LOCATION	□
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-27.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	F. Ss. [illegible]	[illegible]	Ss, fine gr., l gry, [illegible], Sl, vf gr. laminae, horizontal
3	[illegible]	[illegible]	Sl, l gry, fine gr., near horizontal
4,5,6	[illegible]	[illegible]	[illegible]

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
6/8/91: [illegible] carbide-tipped bits on [illegible] roadheader

SCALE 1" = 10'

Geology By | Drawn By | Checked By | Date

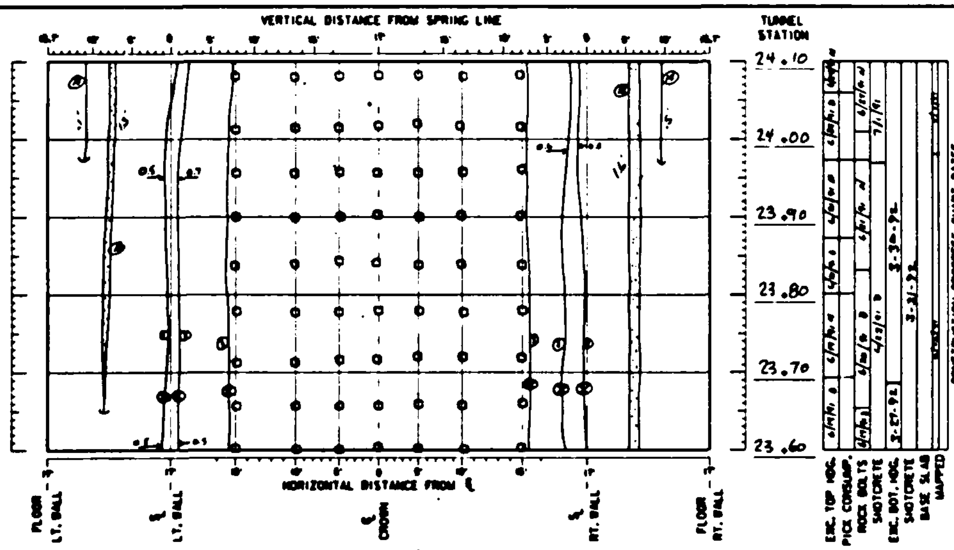
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 3

STATION 23+10 TO 23+60

SHEET 25 OF 57



LEGEND

ROCK BOLT LOCATION	□
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-28.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	F. Ss. [illegible]	[illegible]	Ss, fine gr., l gry, [illegible], Sl, near horizontal, vf gr. lam
3	[illegible]	[illegible]	Sl, l gry, fine gr., horizontal
13	[illegible]	[illegible]	Ss, vf gr., [illegible]
14	[illegible]	[illegible]	Ss, vf gr., [illegible]

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By | Drawn By | Checked By | Date

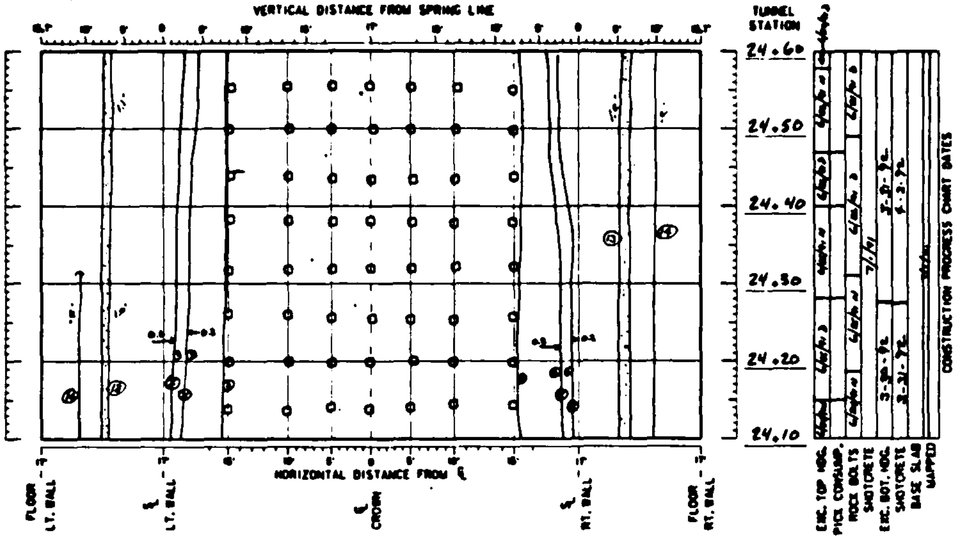
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 3

STATION 23+60 TO 24+10

SHEET 26 OF 57



LEGEND

ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-29 .

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1, 2	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]
13	[illegible]	[illegible]	[illegible]
14	[illegible]	[illegible]	[illegible]

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

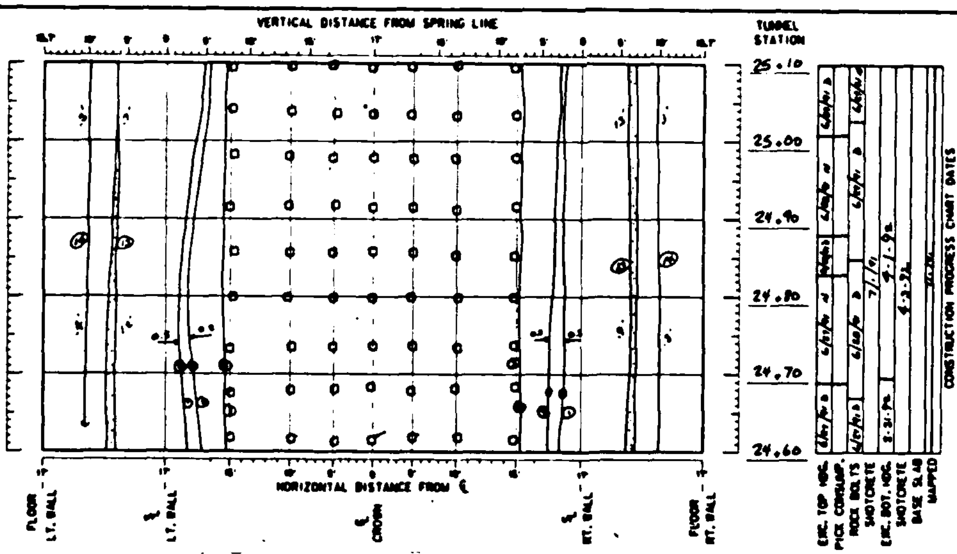
US Army Corps of Engineers

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 3

STATION 24.10 TO 24.60

SHEET 27 OF 37



LEGEND

ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-30 .

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1, 2	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]
13, 14	[illegible]	[illegible]	[illegible]

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers

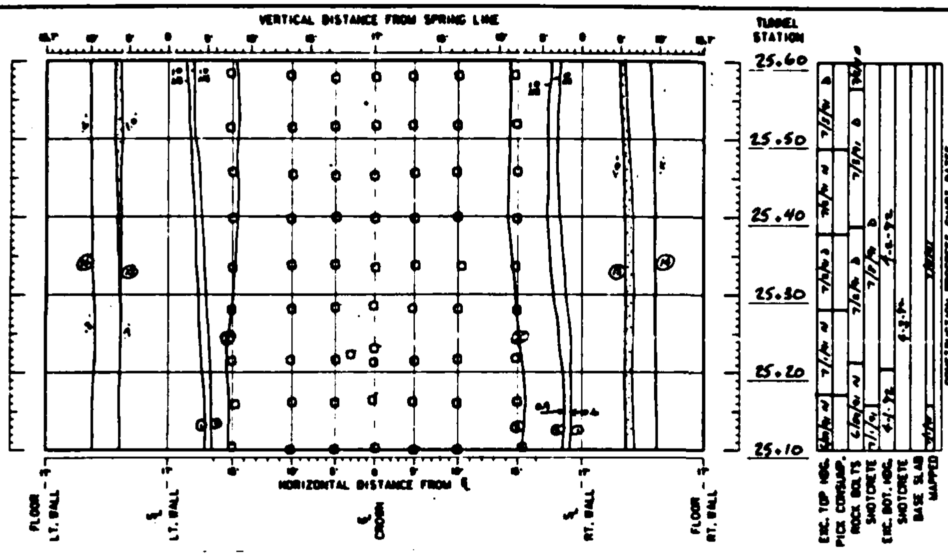
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 3

STATION 24.60 TO 25.10

SHEET 28 OF 37

PLATE D-61



LEGEND

ROCK BOLT LOCATION	□
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-31.

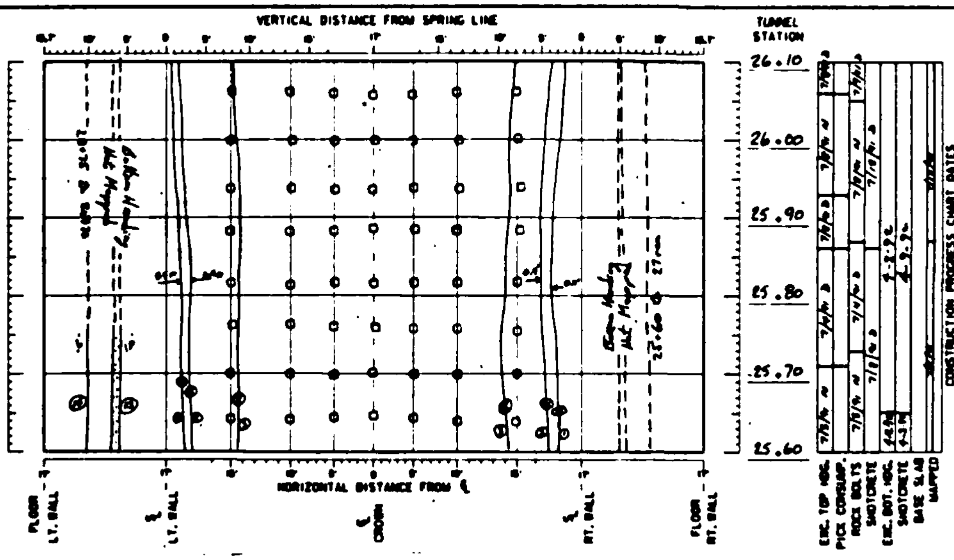
GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	[illegible]	[illegible]	[illegible] Ss. f.gm. l.grs. [illegible] dip 10° [illegible]
3	[illegible]	[illegible]	[illegible] l.grs. [illegible]
13,14	[illegible]	[illegible]	[illegible]

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
7/8/91 – Extra 6/6 (2) at 25+22. Seams ragged cut in crown.

Geology By	US Army Corps of Engineers	HARLAN DIVERSION GEOLOGIC MAPPING
Drawn By	TUNNEL T- 3	
Checked By	STATION 25+10 TO 25+60	
Date	SHEET 29 OF 39	

SCALE 1" = 10'



LEGEND

ROCK BOLT LOCATION	□
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-31,32.

GEOLOGIC MAPPING LEGEND

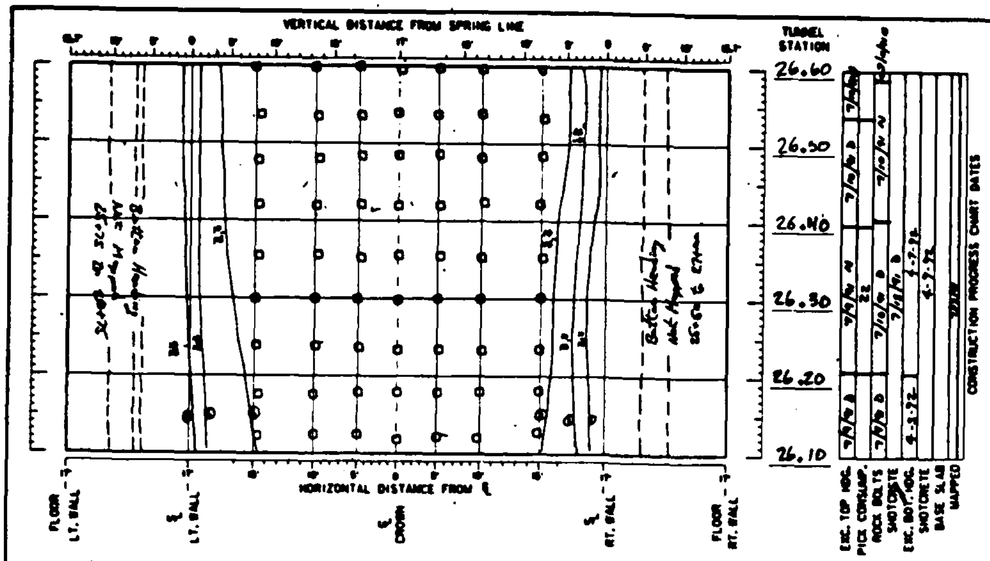
FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	[illegible]	[illegible]	[illegible] Ss. f.gm. l.grs. [illegible] near horizontal
2	[illegible]	[illegible]	[illegible] Ss. f.gm. l.grs. [illegible] near horizontal
3	[illegible]	[illegible]	[illegible] l.grs. f.gm. near horizontal
13	[illegible]	[illegible]	[illegible]
14	[illegible]	[illegible]	[illegible]

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

Geology By	US Army Corps of Engineers	HARLAN DIVERSION GEOLOGIC MAPPING
Drawn By	TUNNEL T- 3	
Checked By	STATION 25+60 TO 26+10	
Date	SHEET 30 OF 39	

SCALE 1" = 10'

PLATE D-62



LEGEND

ROCK BOLT LOCATION	□
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	x
STRIP DRAINS	
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T-3 30,31

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	F. Ss. bdg	Tim Shy	Ss, f-gm, l-gry, M4, W1, B3, planar, dips 10° NE
3	Bdg Pln	Tim Shy	B4, l-gry

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full peripheral method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

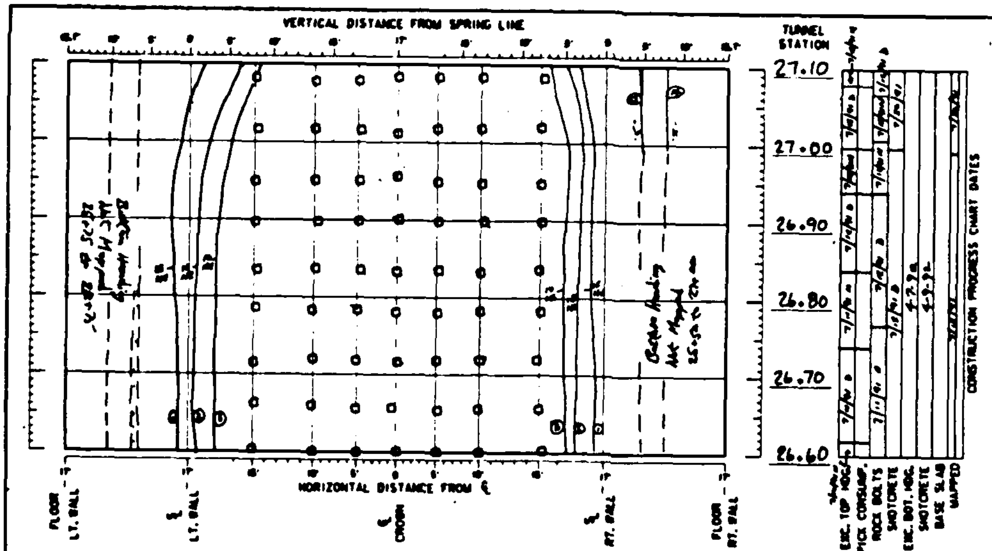
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 3

STATION 26+10 TO 26+60

SHEET 31 OF 39



LEGEND

ROCK BOLT LOCATION	□
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◇
TAPE EX ANCHOR	x
STRIP DRAINS	
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T-3-35.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	F. Ss. bdg	Tim Shy	Ss, f-gm, l-gry, M4, W1, B3, planar, vf-grain, dips 10° NE
3	Bdg pln	Tim Shy	B4, l-gry, Dips 10 NE
18,19	Ss bdg	[illegible]	Ss vf gm. bd [illegible]

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full peripheral method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

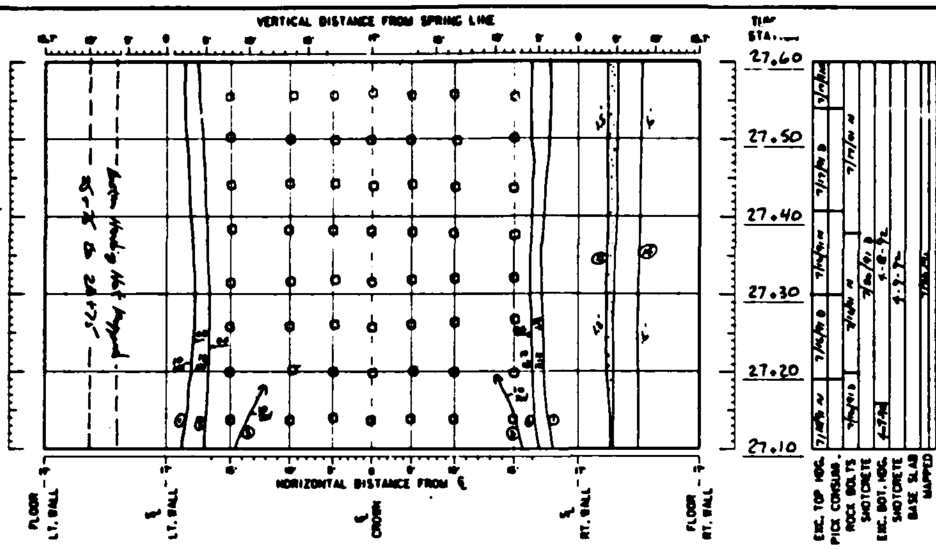
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 3

STATION 26+60 TO 27+10

SHEET 32 OF 39



LEGEND

ROCK BOLT LOCATION	□
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	═
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER 73-36.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	F.Sc.od	Tim Shy	Ss, fine gr., l gray, qtzose, H4, W1, B3; vf gn lams. Dip 10° NE
3	Bdg Pln	Tim Shy	Bd l gray, dips 10° NE, clean in roof - then shoots out.
			at sta. 27+20.
11,14	Sc bed	[illegible]	Ss vf gn. [illegible]

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

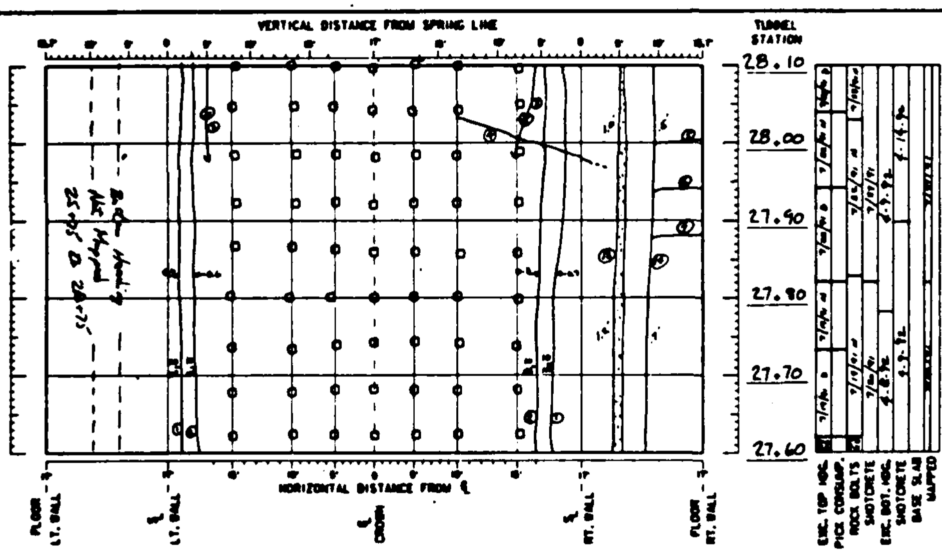
Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 3

STATION 27+10 TO 27+60

SHEET 33 OF 59



LEGEND

ROCK BOLT LOCATION	□
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	═
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER 73-37.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	For.Sc.bd	Tim Shy	Ss, fine gr., l gry, qtzose, H4, W1, B3, vf gn lam, dips 10° NE.
3	F.Sc.bed	Tim Shy	Ss, fine gr., l gr, qtzose, H4, W1, B3, vf gn lam, near horizontal
4	Fracture	Tim Shy	TO [illegible] N... 90
11,14	Sc bed	[illegible]	Ss vf gn. [illegible]
6,6,7	[illegible]	[illegible]	TB [illegible], N70E, 90

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
7/20/91 - Bolts [illegible] to [illegible] when [illegible] bolt installed: sta. 27+74 to 27+80.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

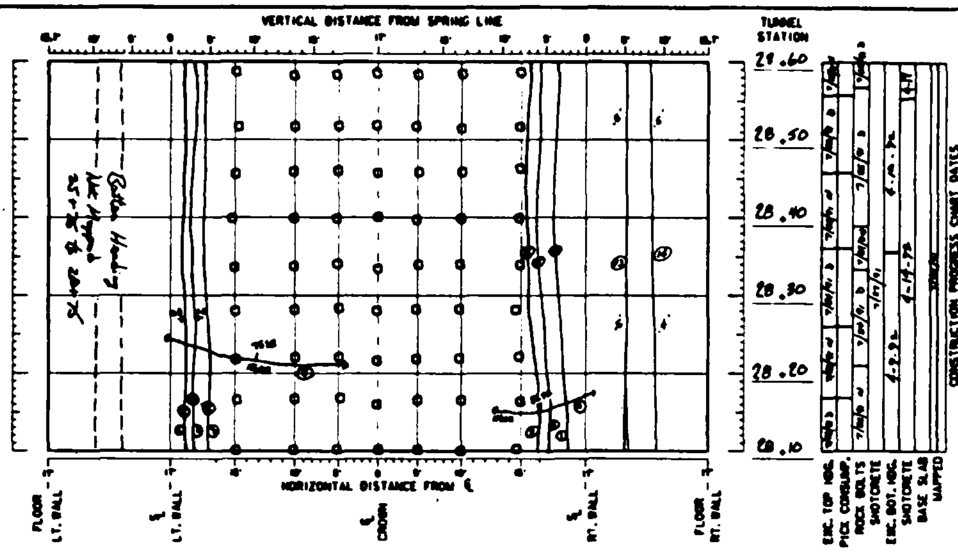
US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 3

STATION 27+60 TO 28+10

SHEET 34 OF 59

PLATE D-64



LEGEND

ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-38.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2,3	[illegible]	[illegible]	Ss, [illegible]
4	Fracture	[illegible]	[illegible] N60°E, 75°SE
5	Fracture	[illegible]	[illegible] N60°E, 86°SE
(13)(14)	[illegible]	[illegible]	[illegible]

REMARKS: Tunnel alignment - N 67°24'45"E.
Mapped geologically using the full peripheral method.
Orientation of strike symbols approximate.
[illegible] - lost power during [illegible] at 1700 [illegible]

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

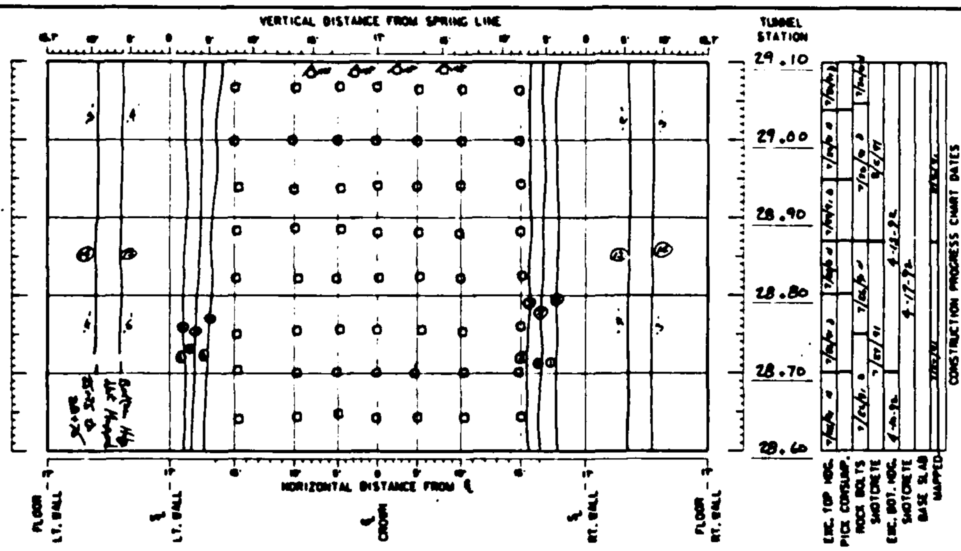
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 3

STATION 28+10 TO 28+60

SHEET 35 OF 59



LEGEND

ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-39.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2,3	[illegible]	[illegible]	SS, Ss, [illegible] horizontal
13,14	[illegible]	[illegible]	[illegible]

REMARKS: Tunnel alignment - N 67°24'45"E.
Mapped geologically using the full peripheral method.
Orientation of strike symbols approximate.
[illegible] - Four additional bolts installed, [illegible] angled 45° towards face.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers

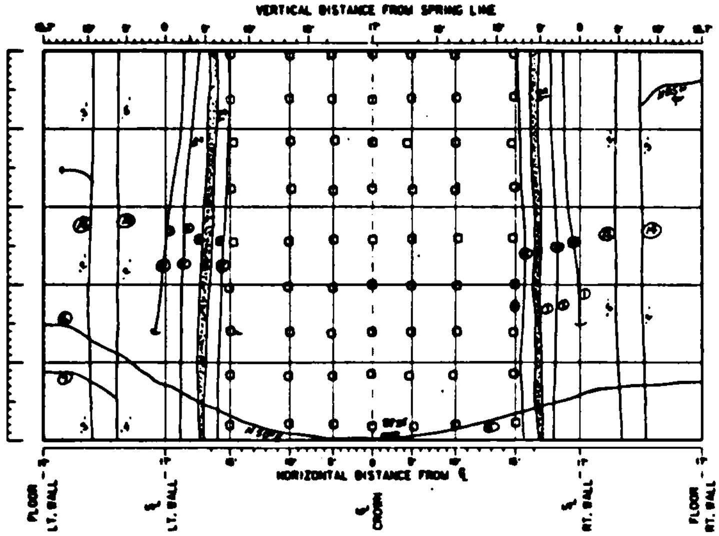
HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 3

STATION 28+60 TO 29+10

SHEET 36 OF 59

PLATE D-65



TUNNEL STATION

29.60
29.50
29.40
29.30
29.20
29.10

EXC. TOP HDG. | PICK CONSUMP. | ROCK BOLTS | SHOTCRETE | EXC. BOT. HDG. | SHOTCRETE | BASE SLAB | MAPPED

CONSTRUCTION PROGRESS CHART DATES

LEGEND

ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-40,41.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2,4	Sh. Bed	Tm.Wy	Sh. Ss, l gr, f gm, M5, M4, Near horizontal
3	F gm Bed	Tm.Wy	Sl. Ss, l gr, f gm, M5, M4, near horizontal
5	Joint	Tm.Wy	C4, O4, T8, R2, HL4, M2, N50°E, 80SE
6	Jt	An	N85E, SE ob T4 R4 HL4 M2
7	Jt	An	N80E, ob T4 R4 HL4 M2
8	Jt	An	N77E SE ob T4 R4 HL4 M2
13	Ss Bed	An	H4 W, R4.3 v fgm, lt gr, thickness indicated
14	Ss Bed	An	Same as (13)

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

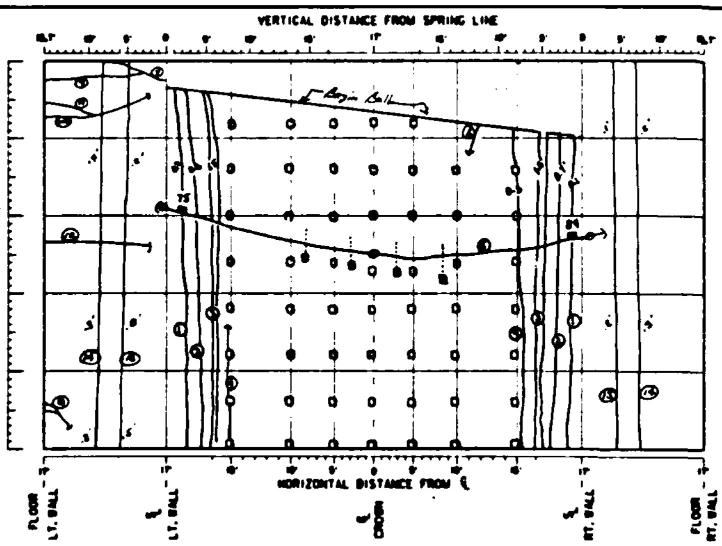
US Army Corps of Engineers

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 3

STATION 29.10 TO 29.60

SHEET 37 OF 39



TUNNEL STATION

30.10
30.00
29.90
29.80
29.70
29.60

EXC. TOP HDG. | PICK CONSUMP. | ROCK BOLTS | SHOTCRETE | EXC. BOT. HDG. | SHOTCRETE | BASE SLAB | MAPPED

CONSTRUCTION PROGRESS CHART DATES

LEGEND

ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
ANGLED ANGLE BOLTS
DRAIN PIPE

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER T3-41,42.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
5	Jt	Pan	D9 (open 0.05ft) T8, R5, HL4, M4, W2, N60E 84-75 SE
1	Ss bd		Sil Ss bed, vf gm, m-s bd, lt gray, variable thickness
2 (12)	Ss bd		0.1' to 1.5'
3 (13)	Ss bd		at Sheeting
4	Ss bd		
6	Sl Ph	Tm.Wy	O4, T8, R5, HL4, M4, W2, Near horizontal, bedding plane
7	Jt	An	N60E 60 SE ob T4 R4 HL4 M3
8	Jt		N80W 65 SW ob T4 R4 HL4 M2
9	Jt		N55E 82 NW ob T4 R4 HL4 M2
10	Jt		N60E 85 NW ob T4 R4 HL4 M3
11	Jt		N65E 72 SE ob T4 R4 HL4 M3
12	Jt		N60E 85 SE ob T4 R4 HL4 M3

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
8-6-91 Nite - 4 extra 12' long bolts installed at 45° thru joint # (5)
shotcrete @ 1200 hrs 8-7-91
3 Drain pipes installed along jt (5)
8-7-91 Night Shift - Hole thru @ 0326 hrs (8-8-91)
All crown and spring bolts mapped on 91 Bolt Station maps.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers

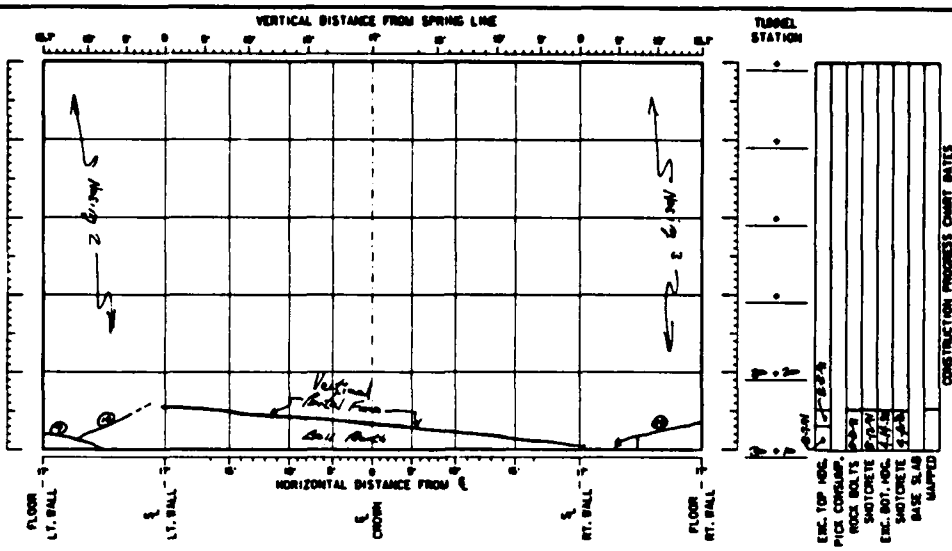
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 3

STATION 29.60 TO 30.10

SHEET 38 OF 39

PLATE D-66



LEGEND

ROCK BOLT LOCATION ---- □
SPBX LOCATION ---- △
MPBX LOCATION ---- ●
LOAD CELL LOCATION ---- ◆
TAPE EX ANCHOR ---- ×
STRIP DRAINS ---- ===
SEEPAGE ----
JOINT ----
FAULT OR SHEAR ----
BEDDING ----
HORIZONTAL BEDS ---- ●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER 73-41.

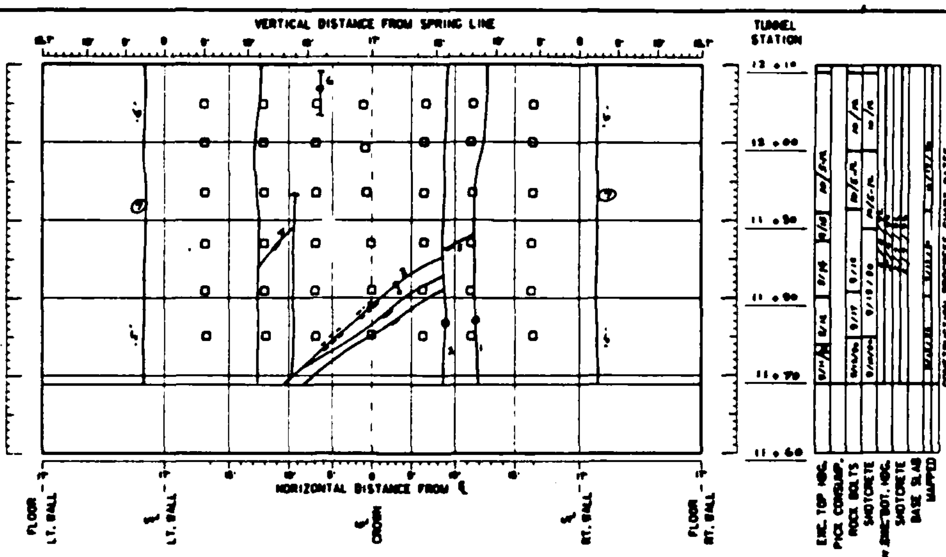
GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
7	St	[illegible]	N60E 60SE [illegible]
13	St	[illegible]	N55E [illegible]
14	St	[illegible]	N70E 85SE [illegible]

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
See Surface Map for Bed [illegible].

SCALE 1" = 10'

Geology By	US Army Corps of Engineers — HARLAN DIVERSION GEOLOGIC MAPPING
Drawn By	TUNNEL T- 3
Checked By	STATION 30+10 TO 30+12
Date	SHEET 37 OF 37



LEGEND

ROCK BOLT LOCATION □
SPBX LOCATION △
MPBX LOCATION ●
LOAD CELL LOCATION ◆
TAPE EX ANCHOR ×
STRIP DRAINS ===
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS ●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ____.

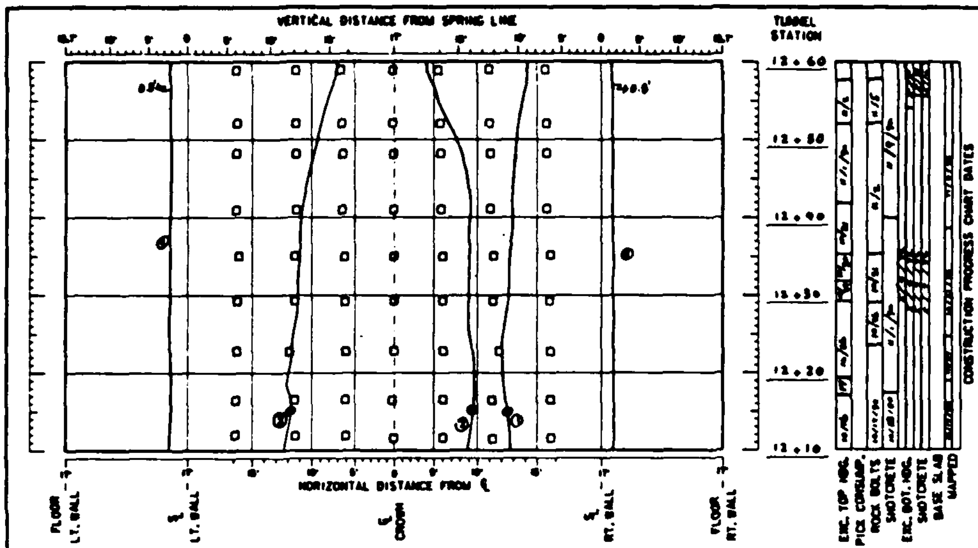
GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION	
1	Bed pln	[illegible]	[illegible]	Horizontal
2	Bed pln		[illegible]	Horizontal
3	Jt Set		[illegible]	N05E, 70NW
4	Jt		[illegible]	N05E, 80NW
5	Jt	[illegible]	[illegible]	N05E, 60NW
6	Jt	[illegible]	[illegible]	Horizontal
7	Bed	[illegible]	[illegible]	

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
[illegible]

SCALE 1" = 10'

Geology By	US Army Corps of Engineers — HARLAN DIVERSION GEOLOGIC MAPPING
Drawn By	TUNNEL T- 4
Checked By	STATION 11+60 TO 12+10
Date	SHEET 1 OF 37



LEGEND

ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Bdd pln	[illegible]	[illegible] Horizontal
2	Bdd pln	[illegible]	[illegible] Horizontal
3	Bdd pln	[illegible]	[illegible] Horizontal
4	Bdd	PB	Ss, near horizontal, v.f.grn., med.gr., H6 B3

REMARKS: Tunnel Alignment - N [illegible]. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.

SCALE 1" = 10'

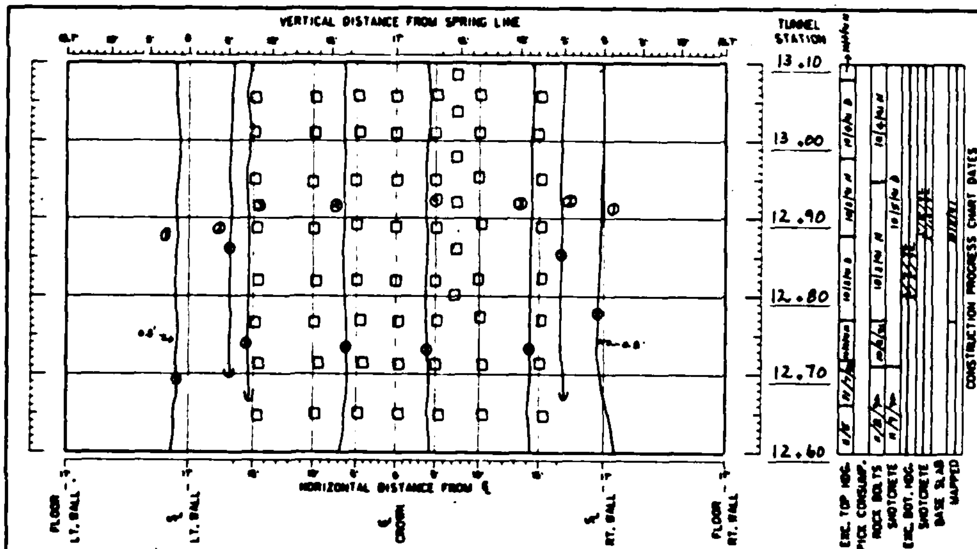
Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 4

STATION 12+10 TO 12+60

SHEET 2 OF 37



LEGEND

ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Ss bd	TS	Ss, near horizontal, [illegible], v.f.grn., lt.gr., H4, W1, B3
2,3	Ss bd.	TS	Ss, near horizontal, [illegible], v.f.grn., lt.gr., H4, W1, B4
4	Bdd pln.	TS	Slabbing edge, near horizontal, [illegible]

REMARKS: Tunnel Alignment - N [illegible]. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.
10/6/81 - Extra bolts: 12+80, 12+86, 12+92, 12+98, 13+04, 13+10

SCALE 1" = 10'

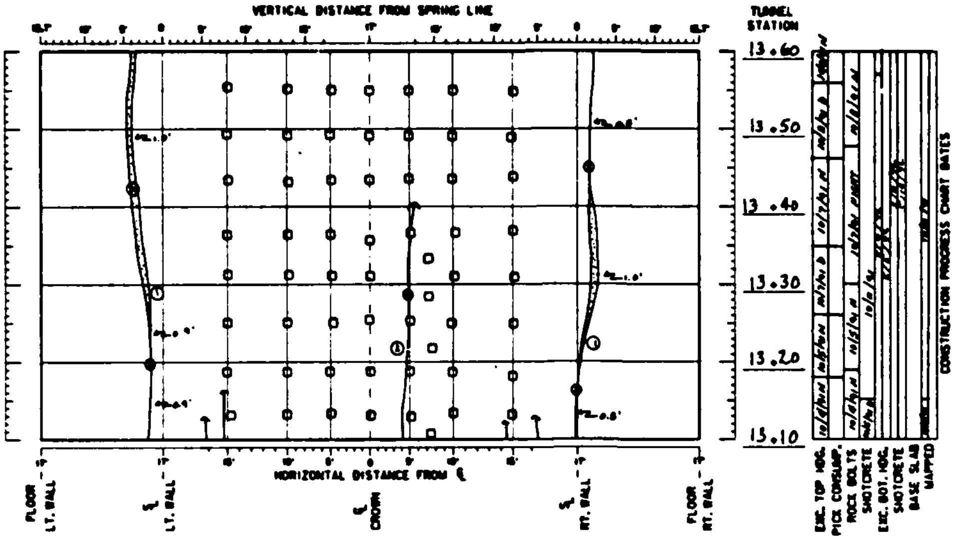
Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 4

STATION 12+60 TO 13+10

SHEET 3 OF 37



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Sa bdd.	T. Sny	Sa, near horizontal, lt.gr., f.grn., planar, H4, W1, B2/B3
2	Bdd. pln.	T. Sny	Slabbing, near horizontal, 05, C4, TK, B2, r.f.4, M2

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full peripheral method.
Orientation of strike symbols approximate.
10/5/81 - Extra bolt at 13+12 to secure slab edge of bedding plane.
10/6/81 - Extra bolts 13+22, 13+28, 13+34 to secure slab edge of bedding plane.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

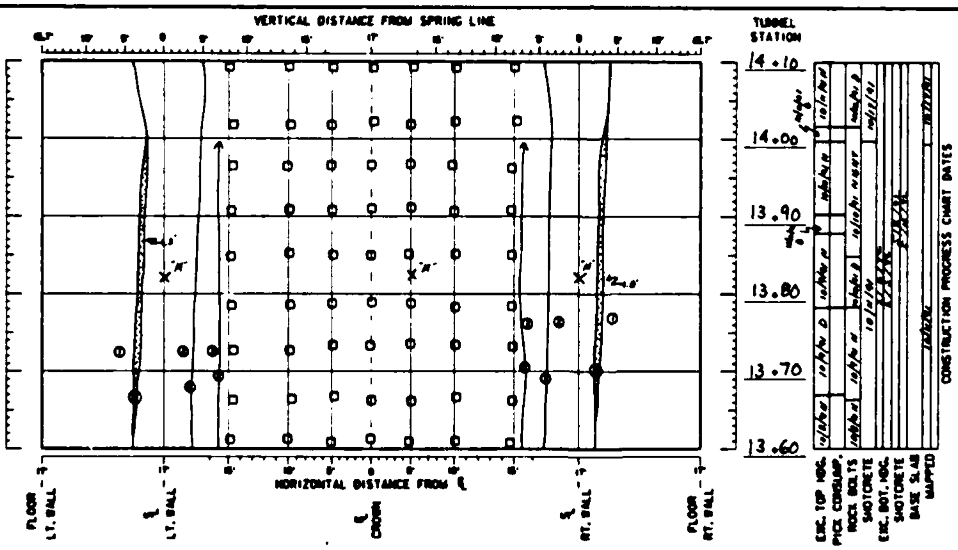
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 4

STATION 13+10 TO 13+60

SHEET 4 OF 37



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Sa Bdd.	T. Sny	Sa, near horizontal, lt.gr., f.grn., planar, H4, W1, B2/B3
2,3	Bdd. pln.	T. Sny	Near horizontal, lt.gr., B2

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full peripheral method.
Orientation of strike symbols approximate.
10/6/81 - TX array "M" at Sta 13+85.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

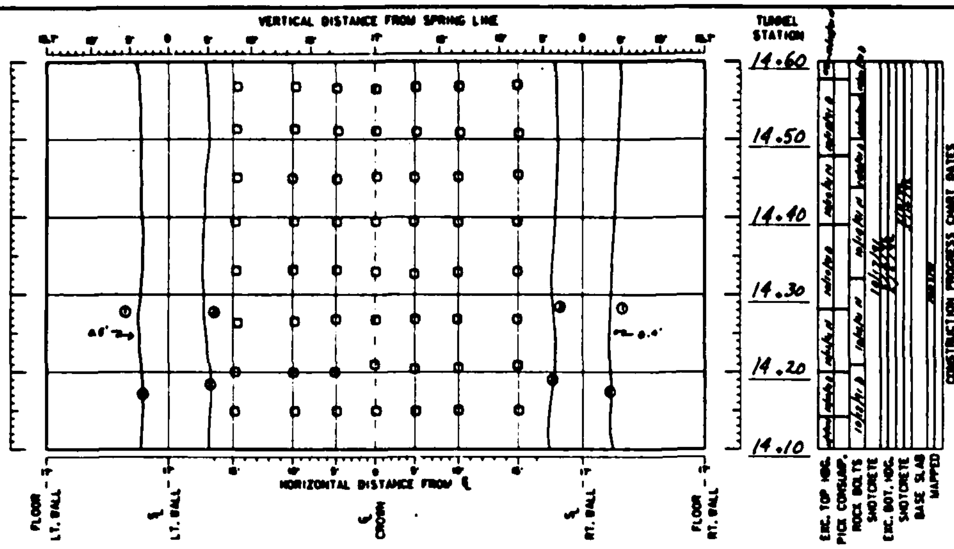
TUNNEL T- 4

STATION 13+60 TO 14+10

SHEET 5 OF 37

VERTICAL DISTANCE FROM SPRING LINE

TUNNEL STATION



LEGEND

ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Ss Bdd	T.SHY	Ss, near horizontal, Hgc, v.f.gm, glauc, H4, wl, Bd
2	Ss Bdd	T.SHY	Ss, near horizontal, Hgc, v.f.gm, glauc, H4, wl, Bd

REMARKS: Tunnel Alignment - N 43°24'45"W. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

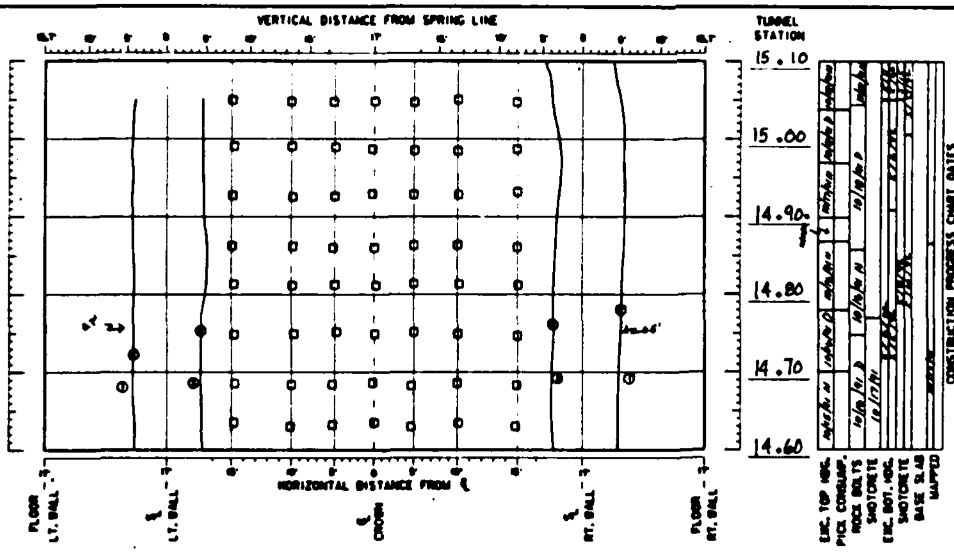
TUNNEL T- 4

STATION 14+10 TO 14+60

SHEET 6 OF 37

VERTICAL DISTANCE FROM SPRING LINE

TUNNEL STATION



LEGEND

ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Ss Bdd	TmShy	Ss, near horizontal, Hgc, v.f.gm, glauc, H4, wl, Bd
2	Ss Bdd	TmShy	Ss, near horizontal, Hgc, v.f.gm, glauc, H4, wl, Bd

REMARKS: Tunnel Alignment - N 43°24'45"W. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

US Army Corps of Engineers

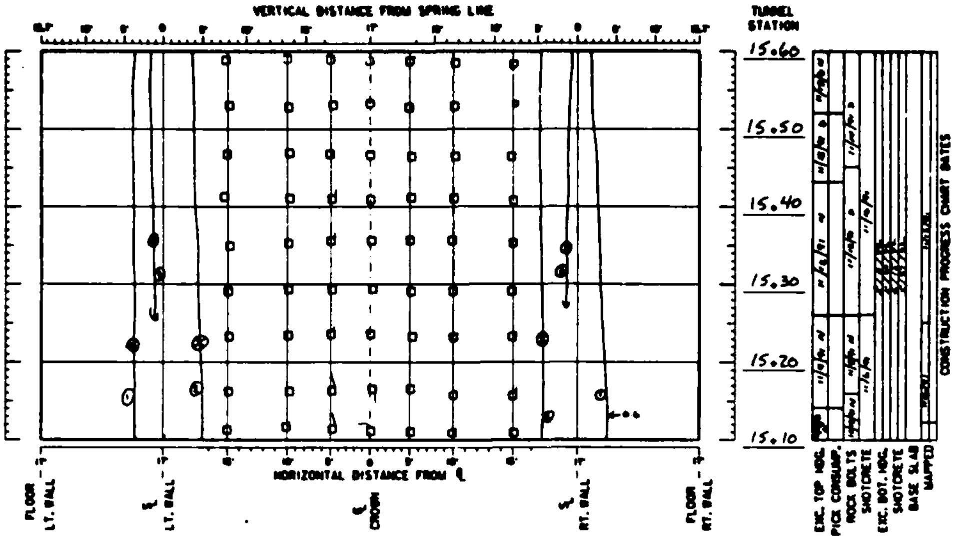
HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 4

STATION 14+60 TO 15+10

SHEET 7 OF 37

PLATE D-70



LEGEND

ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ________.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	ss bed	TN Sty	SS, l gr, v f grn, glauc, H4, W3, B3, near horizontal
3	ss bed	TN Sty	SS l gr, v f grn, H4, W3, B4, glauc, near horizontal

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
4/23/91 - Pourat o/s, right side only
excavated 15+07 to 15+14

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

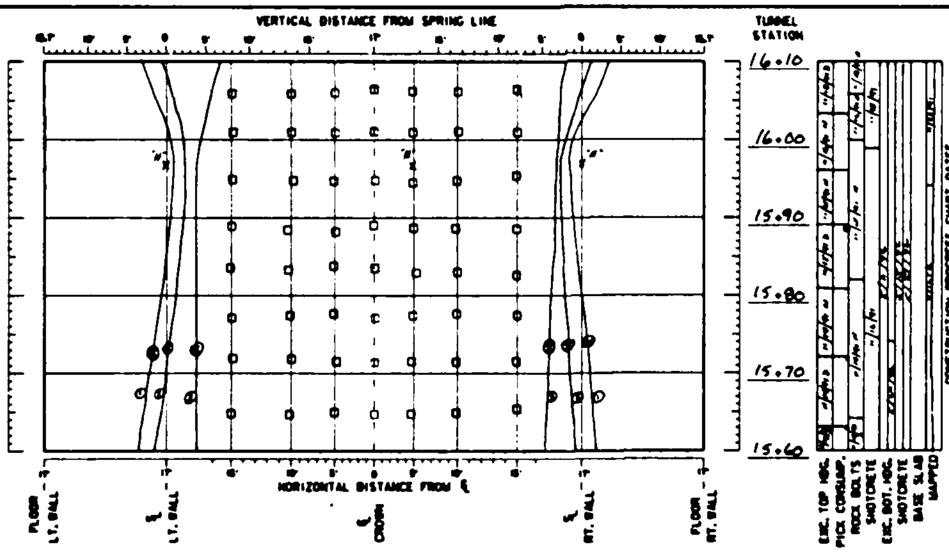
US Army Corps of Engineers

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 4

STATION 15+10 TO 15+60

SHEET 8 OF 37



LEGEND

ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ________.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2,3	SS beds	TN Sty	SS, v f grn, l gr, H4, W3, B4, near horizontal, glauc

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
TX Array 'N' sta. 15+97

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

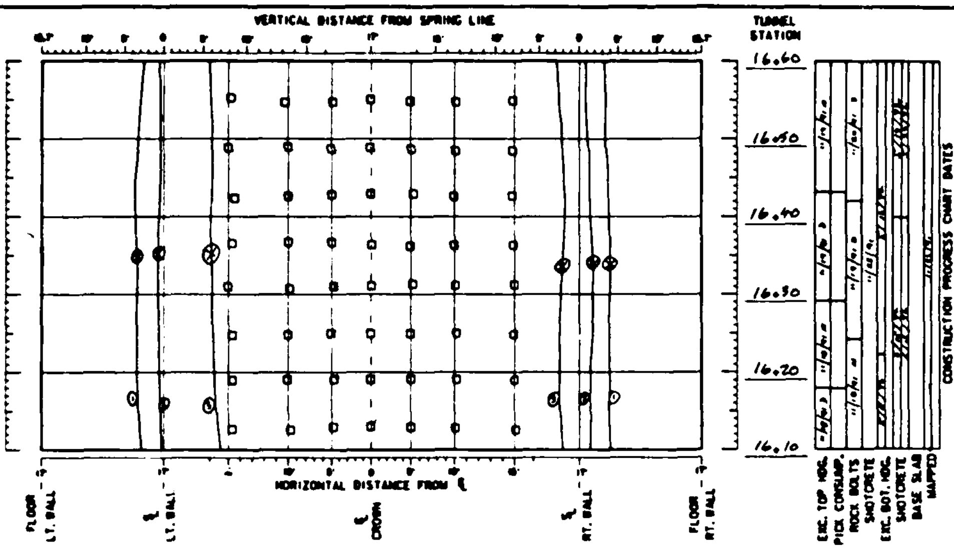
US Army Corps of Engineers

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 4

STATION 15+60 TO 16+10

SHEET 9 OF 37



LEGEND

ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ________.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	SS bedg	Tm Shy	SS, vf gra, lgc, M4, W1, BB, near horizontal, planar
3	SS bedg	Tm Shy	SS, vf gra, lgc, M4, W1, B4, near horizontal, planar

REMARKS: Tunnel alignment - N 43°24'48"W.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

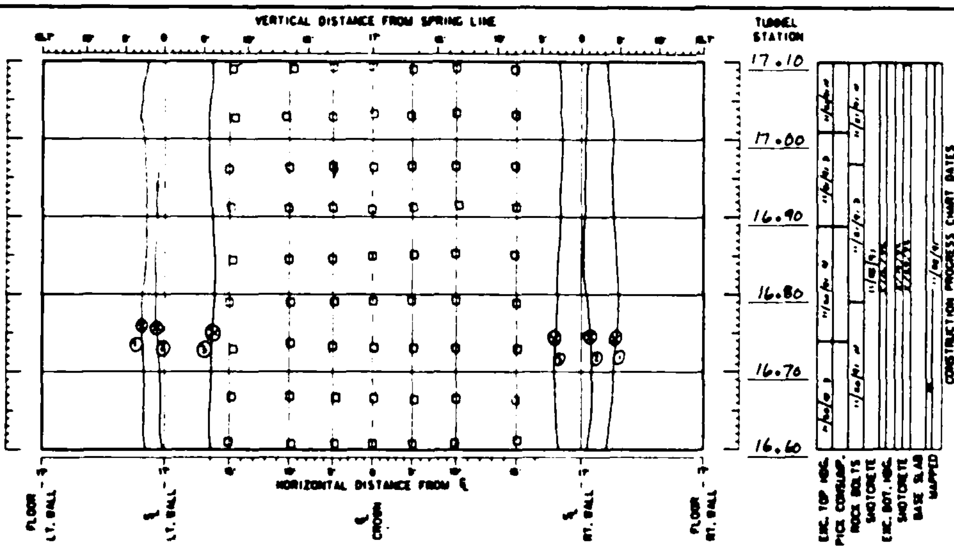
US Army Corps of Engineers

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 4

STATION 16+10 TO 16+60

SHEET 10 OF 37



LEGEND

ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ________.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	SS bed	Tm Shy	SS, vf gra, lgc, M4, W1, B3, near horizontal, planar
3	SS bed	Tm Shy	SS bed, vf gra, lgc, M4, W1, B4, near horizontal, planar

REMARKS: Tunnel alignment - N 43°24'48"W.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers

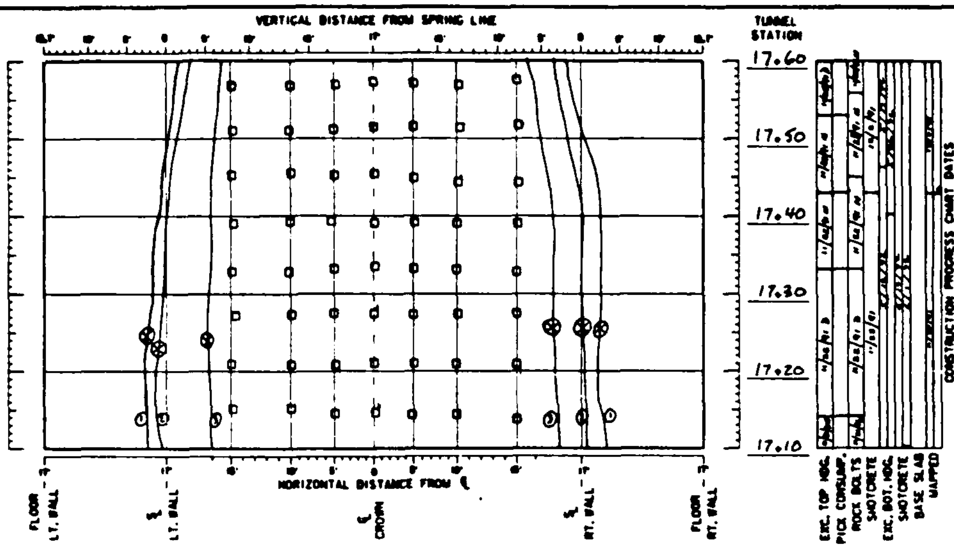
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 4

STATION 16+60 TO 17+10

SHEET 11 OF 37

PLATE D-72



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

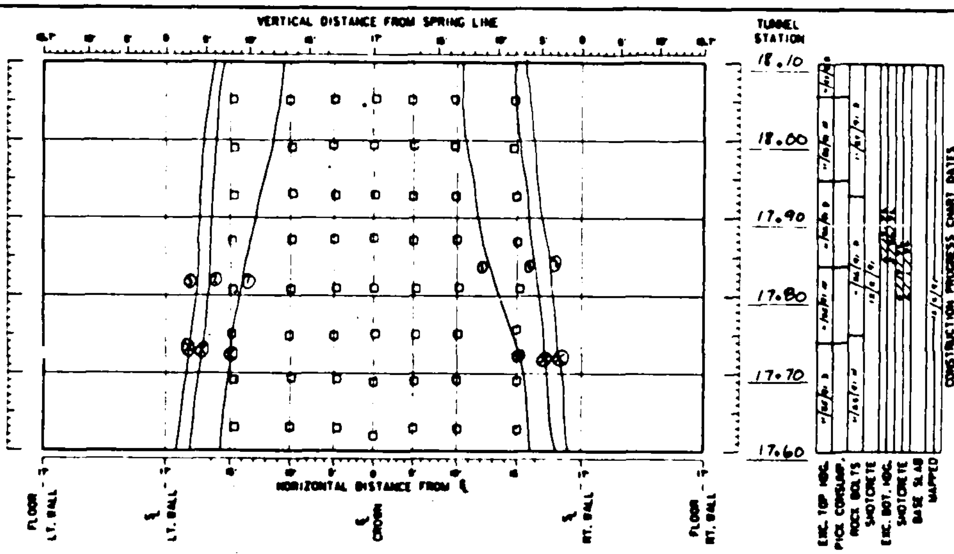
GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1,2	Ss beds	Tla Sby	Ss, v f grn, lgr, H4, w1, B3, planar, near horizontal
3	Ss bed	Tla Sby	Ss, v f grn, lgr, H4, w1, B4, planar, near horizontal

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By	US Army Corps of Engineers — HARLAN DIVERSION GEOLOGIC MAPPING
Drawn By	TUNNEL T- 4
Checked By	STATION 17.10 TO 17.60
Date	SHEET 12 OF 37



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

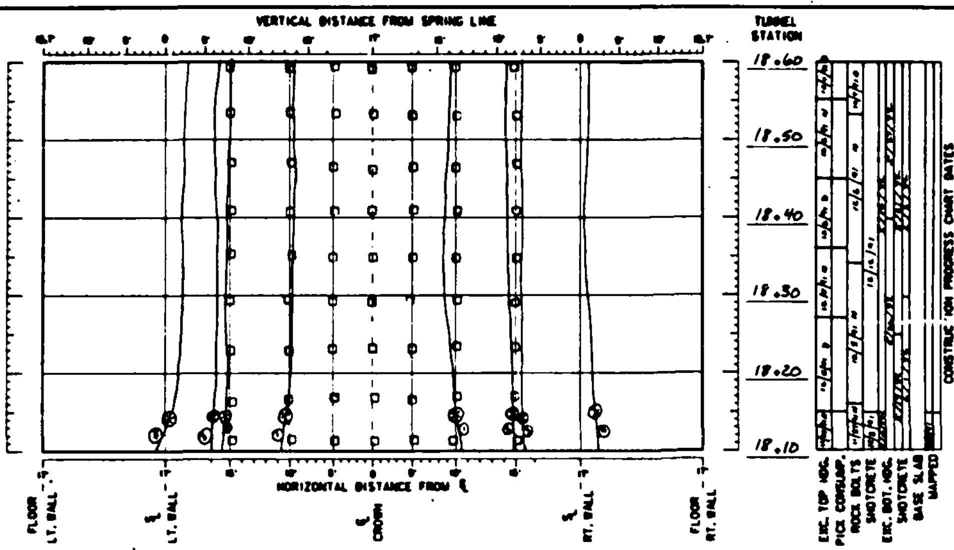
FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Ss bed	Tla Sby	Ss, v f grn, lgr, H4, w1, B4, planar, near horizontal
2	Ss bed	Tla Sby	Ss, v f grn, lgr, H4, w1, B3, planar, near horizontal
3	Ss bed	Tla Sby	Ss, v f grn, lgr, H4, w1, B4, planar, near horizontal

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By	US Army Corps of Engineers — HARLAN DIVERSION GEOLOGIC MAPPING
Drawn By	TUNNEL T- 4
Checked By	STATION 17+60 TO 18.10
Date	SHEET 13 OF 37

PLATE D-73



LEGEND

ROCK BOLT LOCATION	◻
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	SS bed	Tm Sky	SS, v f gm, l gr, H4, W1, B4 near horizontal
2	SS bed	Tm Sky	SS, v f gm, l gr, H4, W1, B3, near horizontal
3	SS bed	Tm Sky	SS, v f gm, l gr, H4, W1, B4, near horizontal
4	SS bed	Tm Sky	SS, v f gm, l gr, H4, W1, B3/B2, near horizontal

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

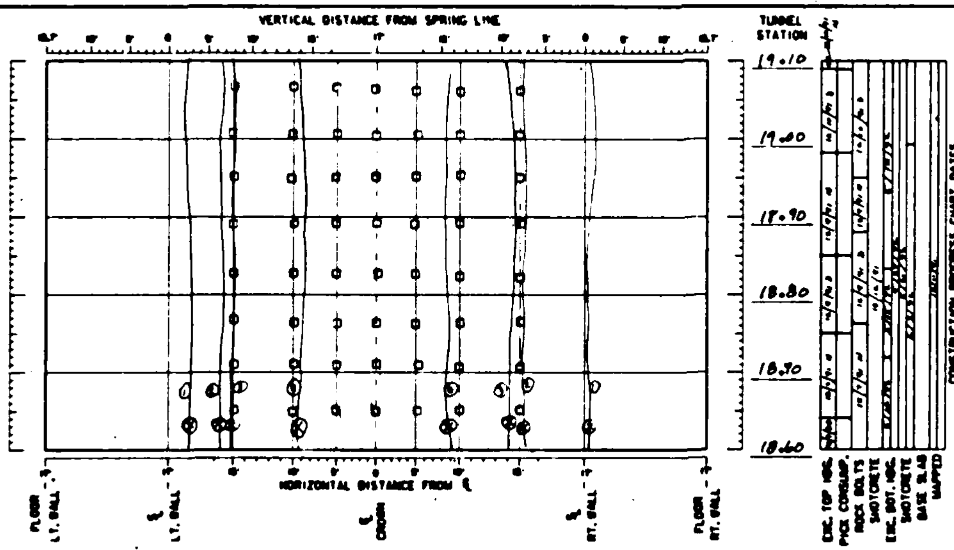
Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 4

STATION 18+10 TO 18+60

SHEET 14 OF 37



LEGEND

ROCK BOLT LOCATION	◻
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	SS bed	Tm Sky	SS, v f gm, l gr, H4, W1, B4, near horizontal, planar
2	SS bed	Tm Sky	SS, v f gm, l gr, H4, W1, B3, near horizontal, planar
3	SS bed	Tm Sky	SS, v f gm, l gr, H4, W1, B4, near horizontal, planar
4	SS bed	Tm Sky	SS, v f gm, l gr, H4, W1, B3/B2, near horizontal, planar

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

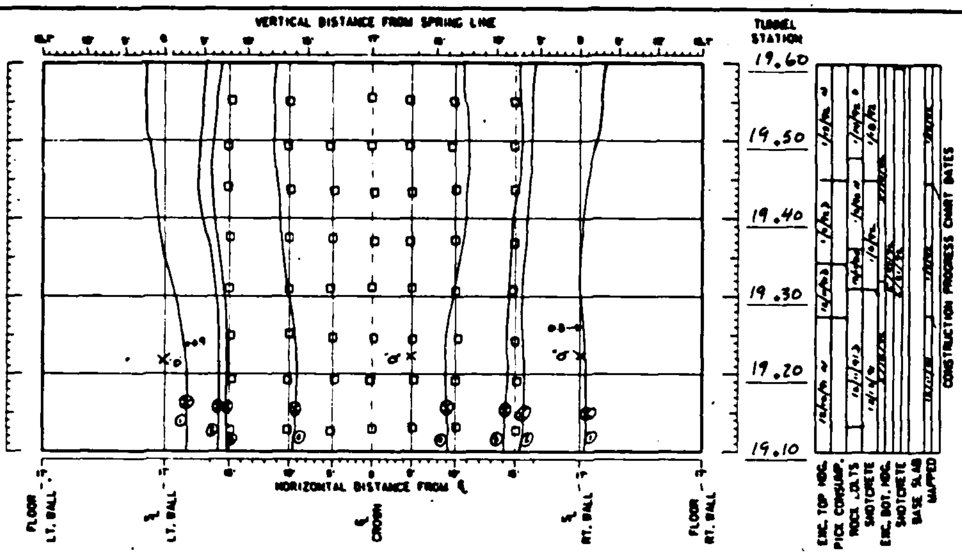
US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 4

STATION 18+60 TO 19+10

SHEET 15 OF 37

PLATE D-74



LEGEND

ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	SS bed	Tm Sly	SS, v f gm, l gr, HY, WI, B3 near horizontal, planar
2	SS bed	Tm Sly	SS, v f gm, l gr, HY, WI, B3, near horizontal, planar
3	SS bed	Tm Sly	SS, v f gm, l gr, HY, WI, B4 near horizontal, planar
4	SS bed	Tm Sly	SS, v f gm, l gr, HY, WI, B3/B4 near horizontal, planar

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
TX array "O" installed 12/10/91.
12/6/91 - Paurat roadheader down due to burned out cutting motor worked briefly on 1/6/92, but motor burned out again
1/13/92 - Paurat worked briefly, then down due to burned out hydraulic motor

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

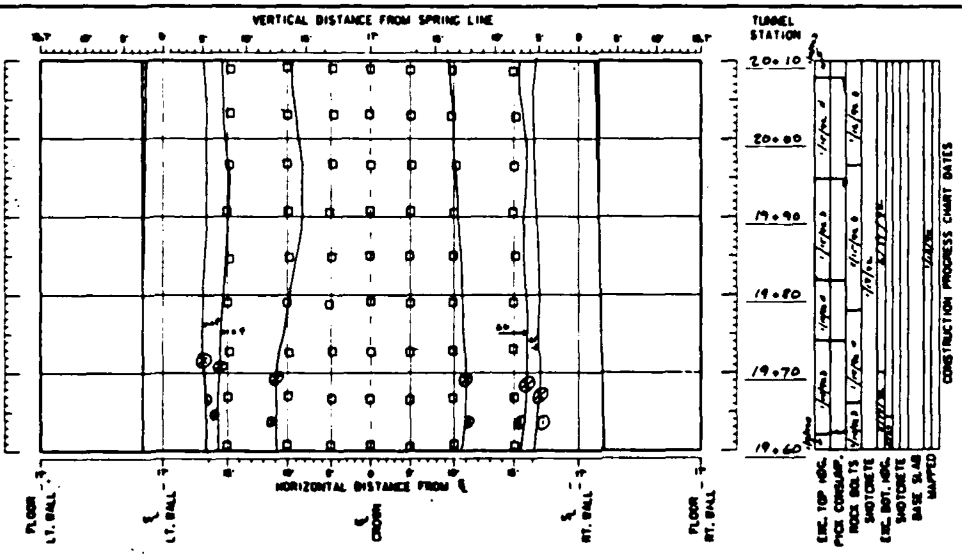
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 4

STATION 19.10 TO 19.60

SHEET 16 OF 37



LEGEND

ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	SS bed	Tm Sly	SS, v f gm, l gr, HY, WI, B3, near horizontal
2	SS bed	Tm Sly	SS, v f gm, l gr, HY, WI, B3, near horizontal
3	SS bed	Tm Sly	SS, v f gm, l gr, HY, WI, B4 near horizontal

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

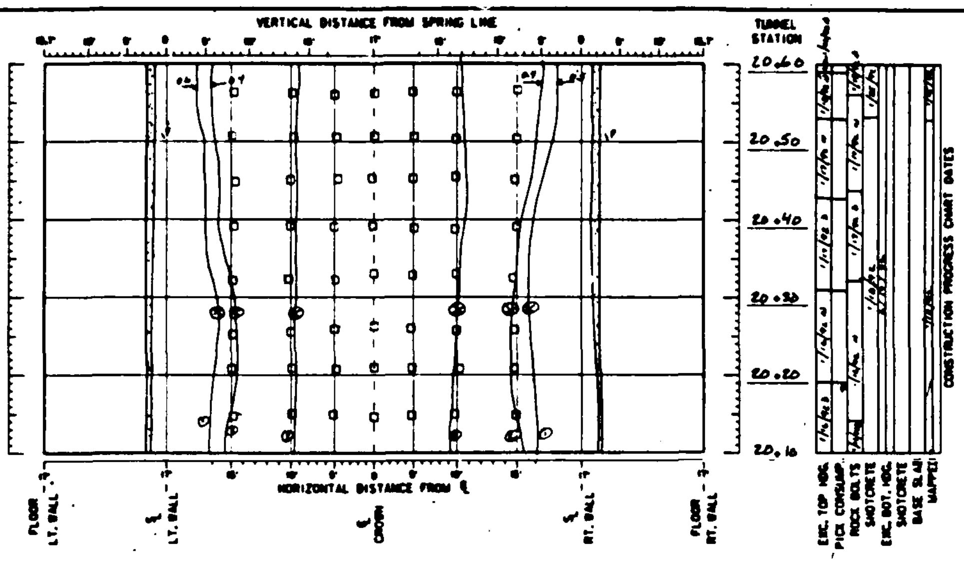
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 4

STATION 19+60 TO 20+10

SHEET 17 OF 37



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Ss bed	Tm Shy	Ss, v f grn, lgr, H4, wi, B3, appr horizontal
2	Ss bed	Tm Shy	Ss, v f grn, lgr, H4, wi, B3, appr horizontal
3	Ss bed	Tm Shy	Ss, v f grn, lgr, H4, wi, B4, appr horizontal

REMARKS: Tunnel Alignment - [illegible]
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

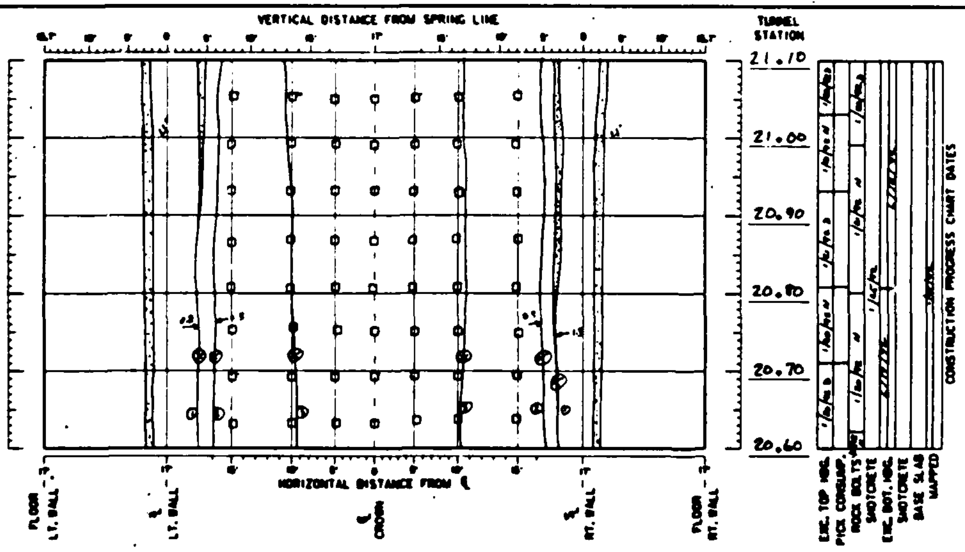
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 4

STATION 20+10 TO 20+60

SHEET 18 OF 37



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Ss bed	Tm Shy	Ss, v f grn, lgr, H4, wi, B3/B4, appr horizontal, [illegible]
2	Ss bed	Tm Shy	Ss, v f grn, lgr, H4, wi, B4, appr horizontal, [illegible]
3	Ss bed	Tm Shy	Ss, v f grn, lgr, H4, wi, B3/B4, appr horizontal, [illegible]

REMARKS: Tunnel Alignment - [illegible]
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers

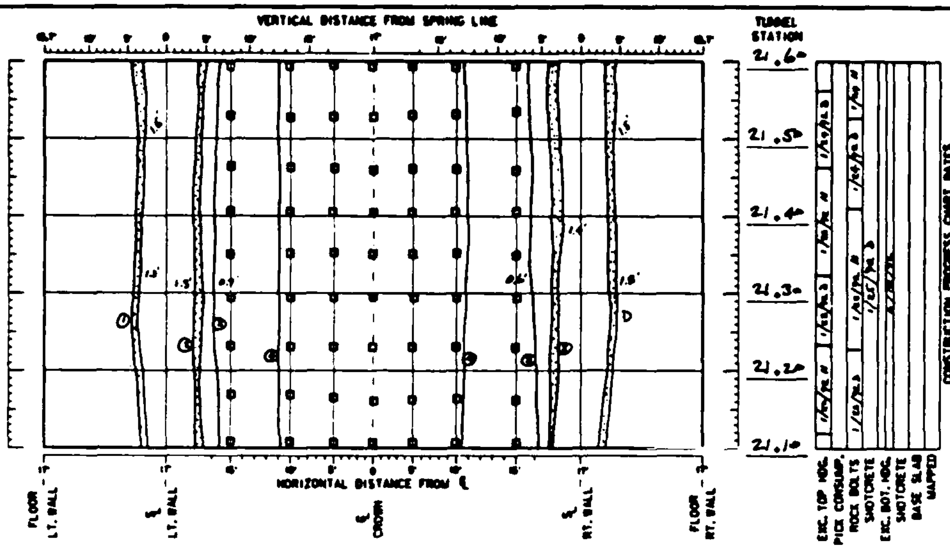
HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 4

STATION 20+60 TO 21+10

SHEET 19 OF 37

PLATE D-76



LEGEND

ROCK BOLT LOCATION ◻
SPBX LOCATION △
MPBX LOCATION ●
LOAD CELL LOCATION ◆
TAPE EX ANCHOR ×
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS ●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1-4	Ss bed	TS	Ss, v f grn, lgt. [illegible]

REMARKS: Tunnel Alignment - N 43°24'45"W.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

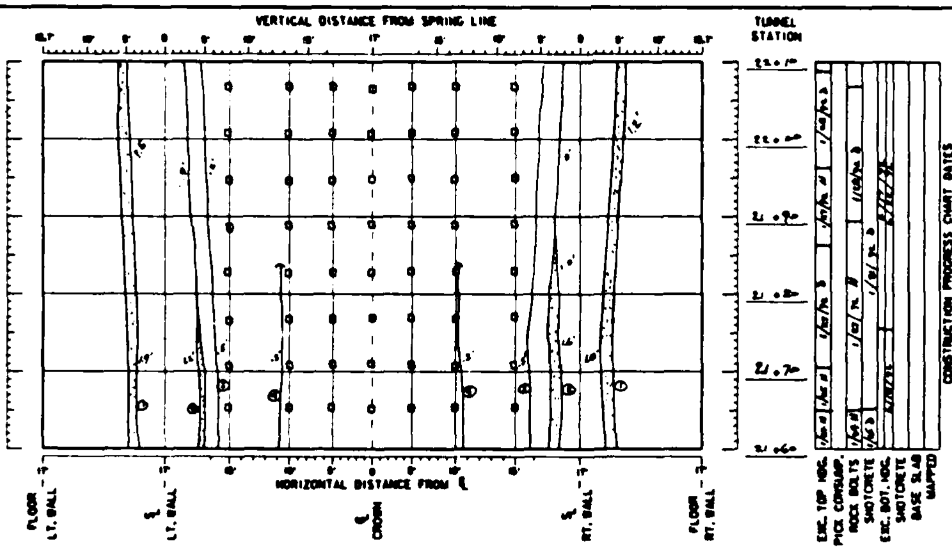
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 4

STATION 21+10 TO 21+60

SHEET 20 OF 37



LEGEND

ROCK BOLT LOCATION ◻
SPBX LOCATION △
MPBX LOCATION ●
LOAD CELL LOCATION ◆
TAPE EX ANCHOR ×
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS ●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1-9	Ss beds	TS TR	Ss, v f grn, lgt. [illegible]

REMARKS: Tunnel Alignment - N 43°24'45"W.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
[illegible] 21+65, 21+71 ...

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

US Army Corps of Engineers

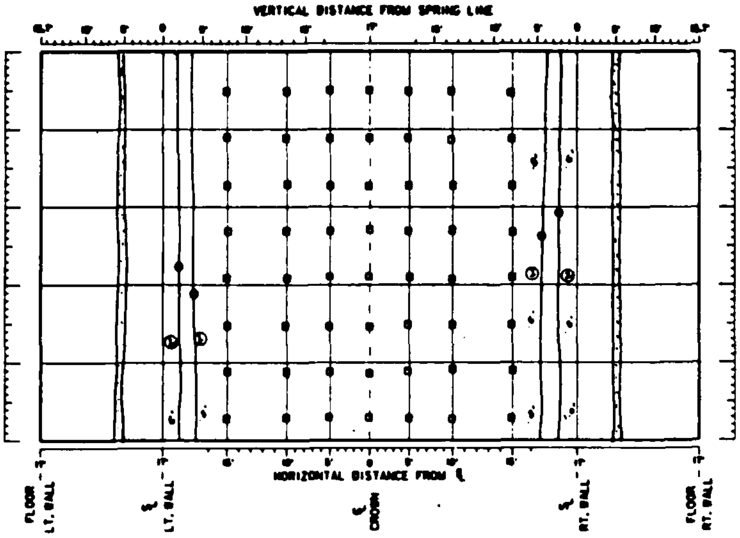
HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 4

STATION 21+60 TO 22+10

SHEET 21 OF 37

PLATE D-77



EXC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED

CONSTRUCTION PROGRESS CHART DATES

LEGEND

ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1, 2	Sc bedx	[illegible]	[illegible]

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

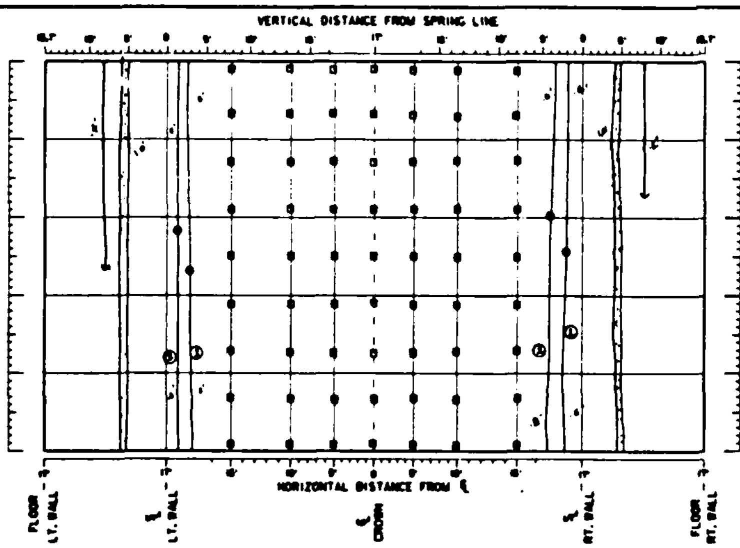
US Army Corps of Engineers

MARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 4

STATION ___+___ TO ___+___

SHEET 22 of 37



EXC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED

CONSTRUCTION PROGRESS CHART DATES

LEGEND

ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1, 2	Sc bedx	[illegible]	[illegible]

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By

Drawn By

Checked By

Date

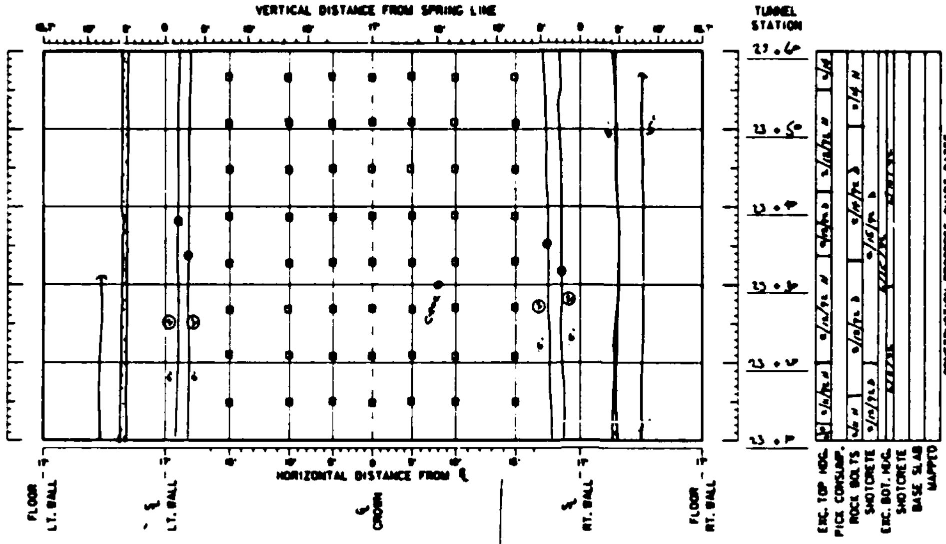
US Army Corps of Engineers

MARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 4

STATION 22+60 TO 23+10

SHEET 23 of 37



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	[illegible]	[illegible]	[illegible]

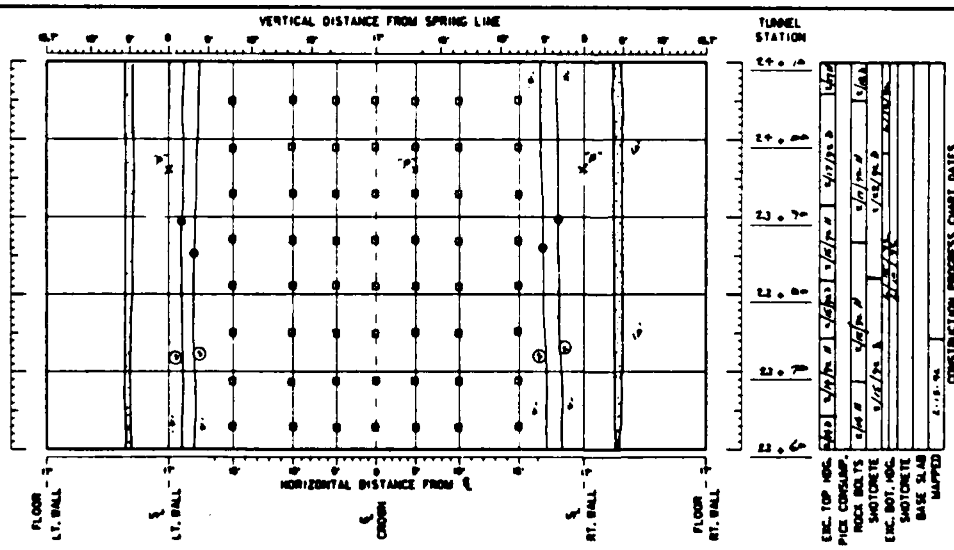
REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full peripheral method.
Orientation of strike symbols approximate.
Vent Conc Hole (open) @ Sta. 23+30.
[illegible] 2nd [illegible]
[illegible]
[illegible]
Installed TX at Sta. 23+97 (6-17-74)

SCALE 1" = 10'
10 0 10 20

Geology By ______
Drawn By ______
Checked By ______
Date ______

US Army Corps of Engineers
HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 4
STATION 23 + 10 TO 23 + 60
SHEET 24 OF 37



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	[illegible]	[illegible]	[illegible] thickness indicated.

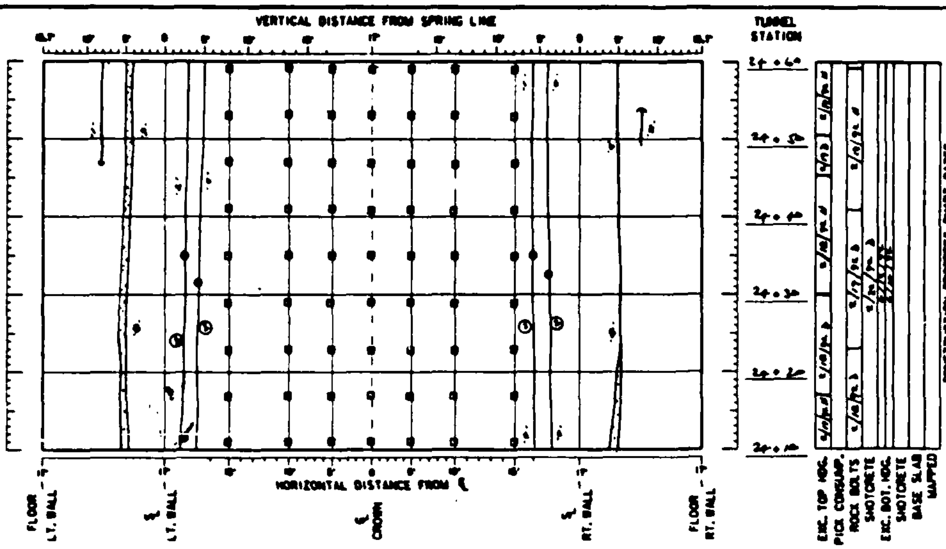
REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full peripheral method.
Orientation of strike symbols approximate.
Bolts 28, 68, 69
TX pts at 23+96 [illegible] "P"

SCALE 1" = 10'
10 0 10 20

Geology By ______
Drawn By ______
Checked By ______
Date ______

US Army Corps of Engineers
HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 4
STATION 23 + 60 TO 24 + 10
SHEET 25 OF 37



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1-2	Bdg. Pl.	[illegible]	Sh. bdg. [illegible] gry, [illegible] gry, [illegible], mostly [illegible], thickness [illegible]

REMARKS: Tunnel Alignment - N 43°24'46"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
Bolts 24+10 [illegible]

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

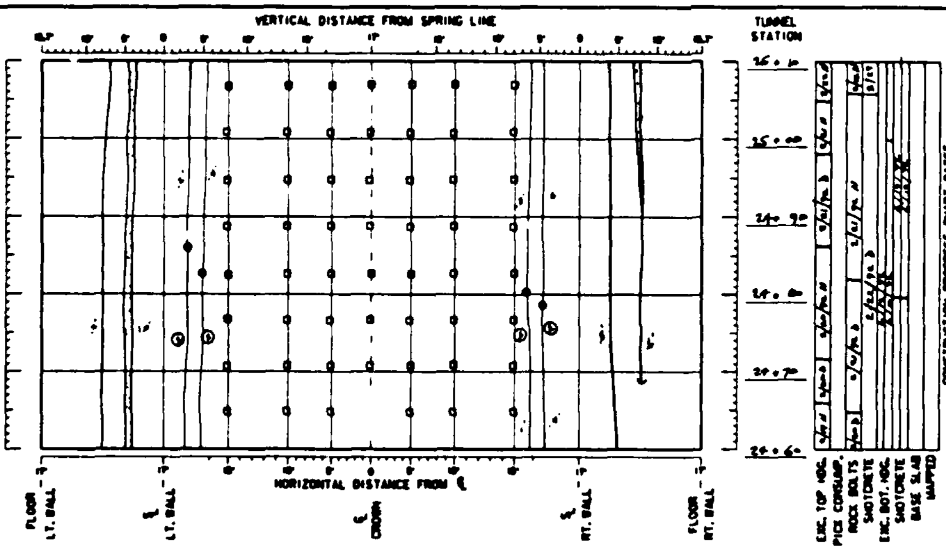
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 4

STATION 24+10 TO 24+60

SHEET 26 of 37



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1-2	Sh. bdg.	[illegible]	Sh. bdg. [illegible] gry, lt gry, [illegible], [illegible] [illegible]

REMARKS: Tunnel Alignment - N 43°24'46"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
Bolts 24+60 [illegible]

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers

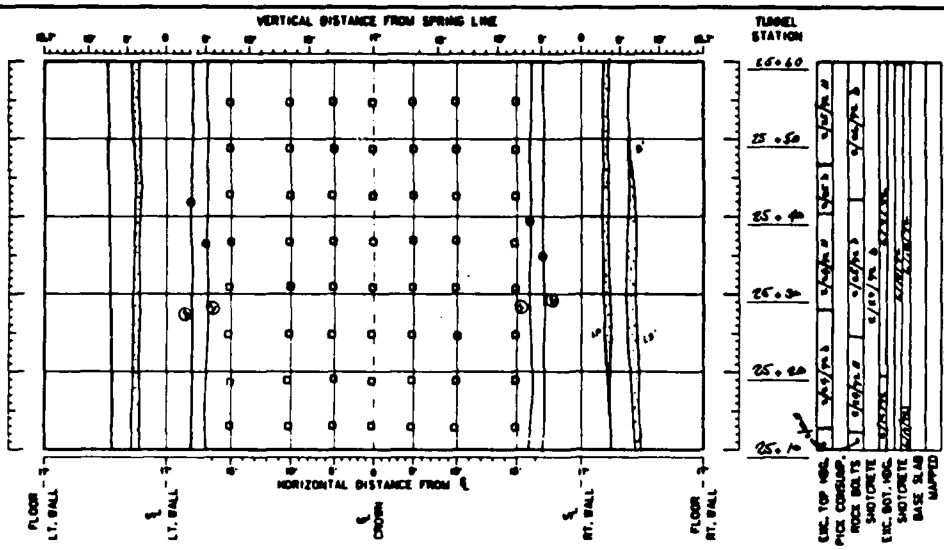
HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 4

STATION 24+60 TO 25+10

SHEET 27 of 37

PLATE D-80



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1, 2	[illegible]	[illegible]	[illegible]

REMARKS: Tunnel Alignment - N 43°24'45"E. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.

SCALE 1" = 10'

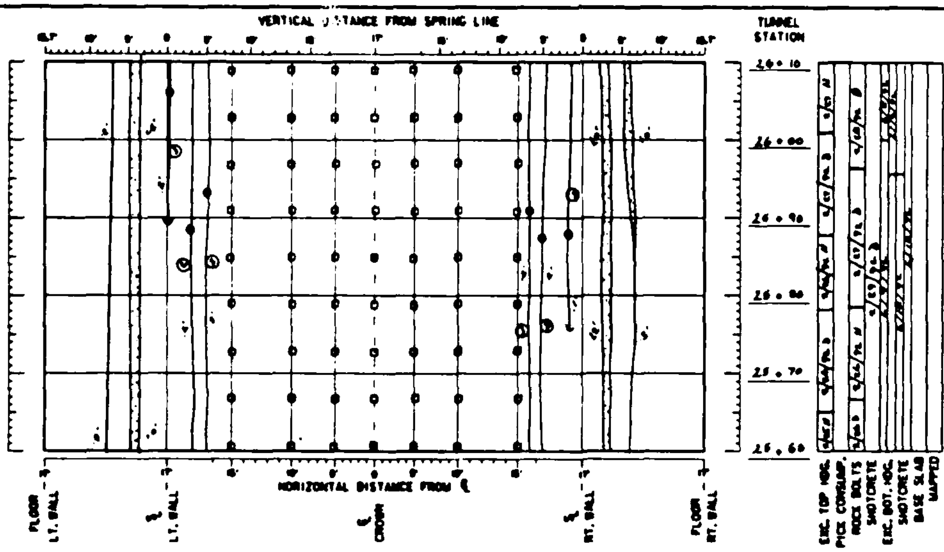
Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 4

STATION 25+10 TO 25+60

SHEET 28 OF 37



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1 & 2	[illegible]	[illegible]	[illegible]

REMARKS: Tunnel Alignment - N 43°24'45"E. Mapped geologically using the full periphery method. Orientation of strike symbols approximate.

SCALE 1" = 10'

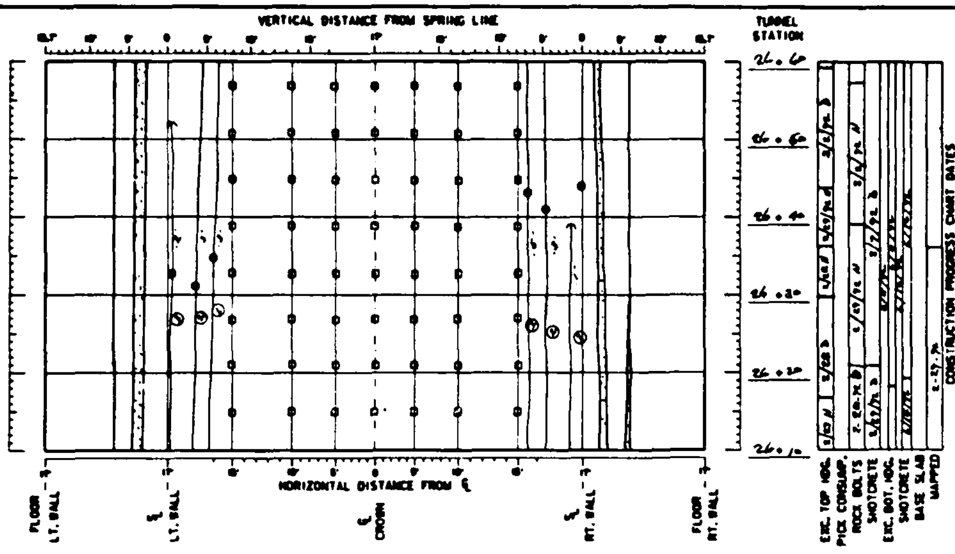
Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 4

STATION 25+60 TO 26+10

SHEET 29 OF 37



LEGEND

ROCK BOLT LOCATION	□
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1 & 3	Sebade	[illegible]	Sebade bd y Egm K gr namly hav thickness indicated

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.

SCALE 1" = 10'

Geology By ______
Drawn By ______
Checked By ______
Date ______

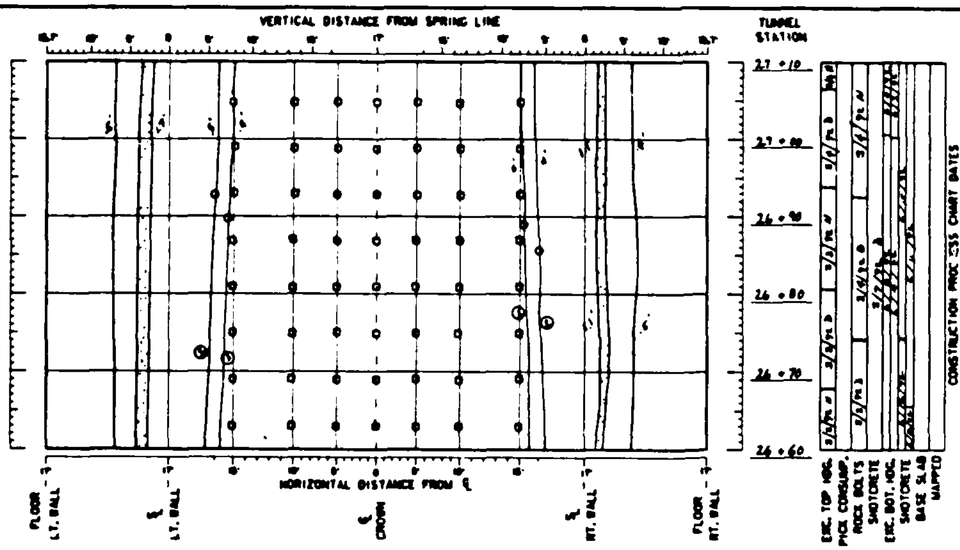
US Army Corps of Engineers

HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T-4

STATION 26+10 TO 26+60

SHEET 30 OF 37



LEGEND

ROCK BOLT LOCATION	□
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1, L	[illegible]	PR	[illegible] bd, v.Egm, K gr, ss, [illegible], thickness indicated

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
Rock Burn 26+68, 69 ...

SCALE 1" = 10'

Geology By ______
Drawn By ______
Checked By ______
Date ______

US Army Corps of Engineers

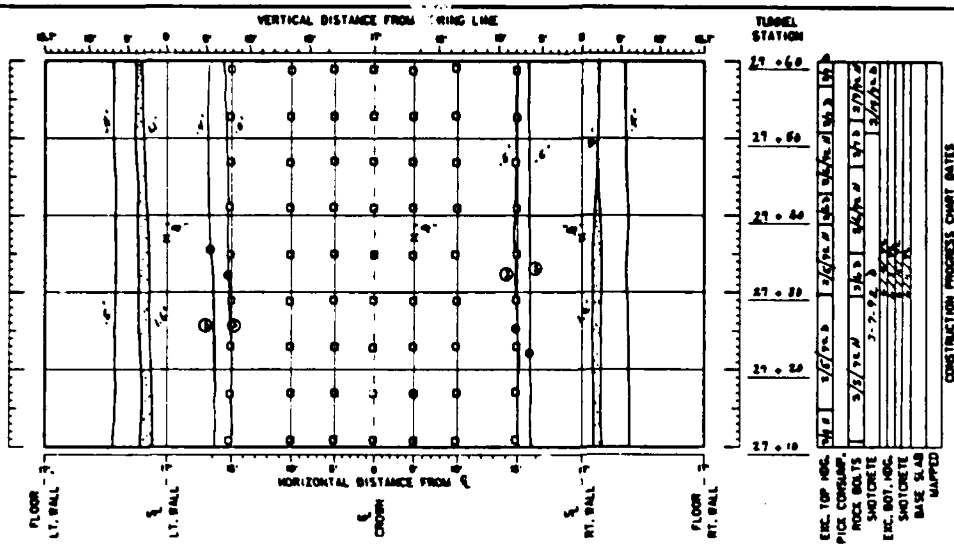
HARLAN DIVERSION
GEOLOGIC MAPPING

TUNNEL T- 4

STATION 26+60 TO 27+10

SHEET 31 OF 37

PLATE D-82



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
2, 3	[illegible]	PR	80/85, hd, r.f. gou, [illegible], thickness indicated

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
ROCK BOLTS 27+11, 17 ...
FACE 27+51 } 3/7/92
[illegible] 27+47 }
TX [illegible] 27+37

SCALE 1" = 10'

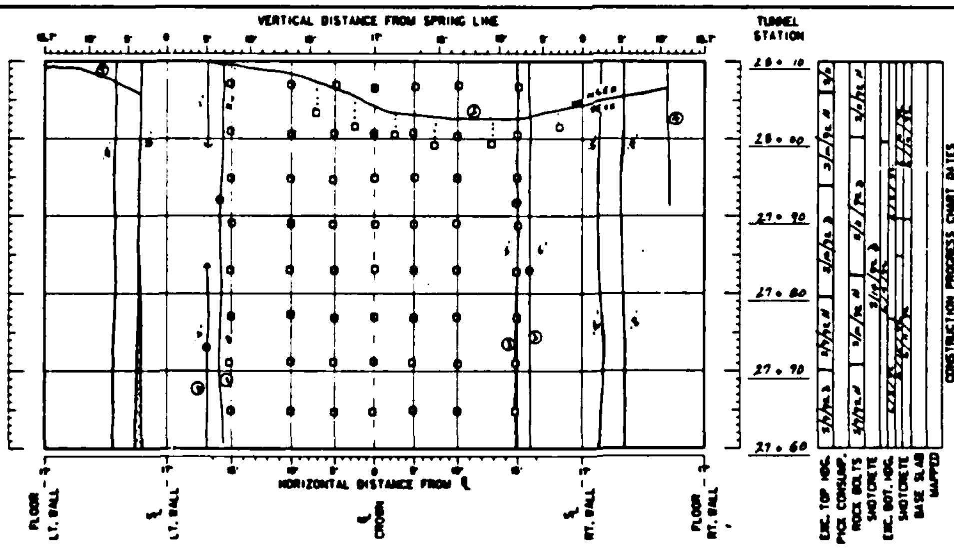
Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers
HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 4

STATION 27+10 TO 27+60

SHEET 32 OF 37



LEGEND

- ROCK BOLT LOCATION
- SPBX LOCATION
- MPBX LOCATION
- LOAD CELL LOCATION
- TAPE EX ANCHOR
- STRIP DRAINS
- SEEPAGE
- JOINT
- FAULT OR SHEAR
- BEDDING
- HORIZONTAL BEDS

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Joint	PAR	[illegible]
2, 3	[illegible]	PAR	[illegible], thickness indicated
4	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]

REMARKS: Tunnel alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
Rock Bolts 27+65, 71

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

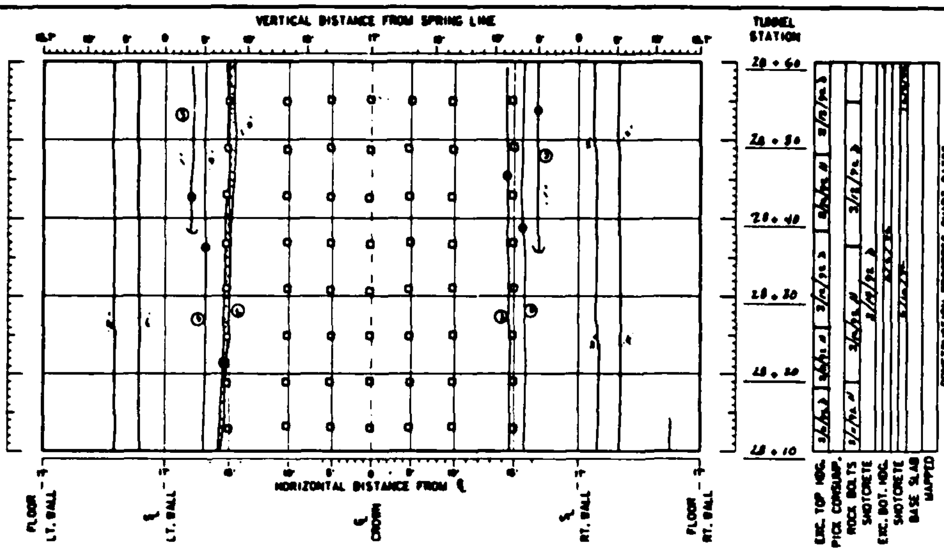
US Army Corps of Engineers
HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 4

STATION 27+60 TO 28+10

SHEET 33 OF 37

PLATE D-83



LEGEND

ROCK BOLT LOCATION	□
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	≡
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
[illegible]	Beds	[illegible]	[illegible], SS, nearly horizontal, [illegible]

REMARKS: Tunnel Alignment - N 43°24'45"E
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
[illegible]

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

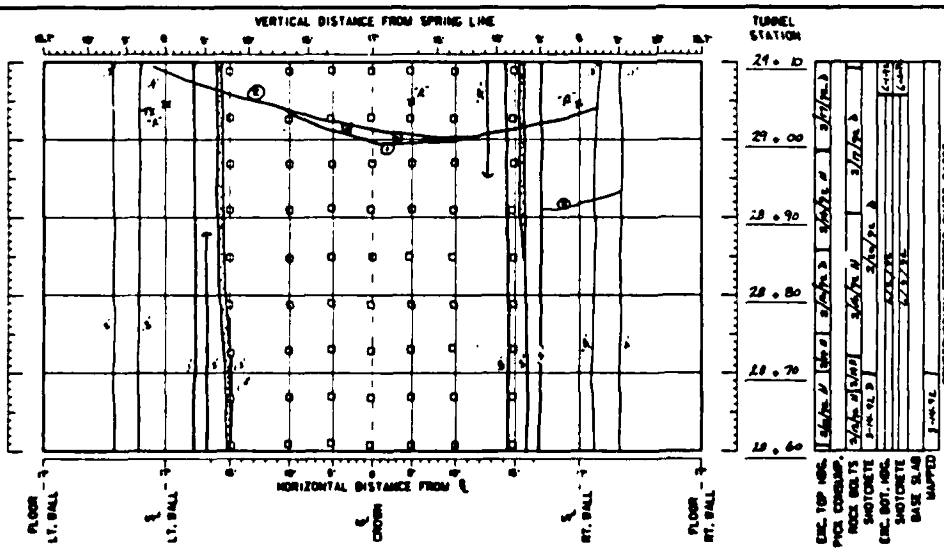
US Army Corps of Engineers

HARLAN DIVERSION GEOLOGIC MAPPING

TUNNEL T- 4

STATION 28+10 TO 28+60

SHEET 34 of 37



LEGEND

ROCK BOLT LOCATION	□
SPBX LOCATION	△
MPBX LOCATION	●
LOAD CELL LOCATION	◆
TAPE EX ANCHOR	×
STRIP DRAINS	≡
SEEPAGE	
JOINT	
FAULT OR SHEAR	
BEDDING	
HORIZONTAL BEDS	●

FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.

FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.

FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER ______.

GEOLOGIC MAPPING LEGEND

FEATURE NUMBER	STRUCTURE	MAPPED BY	DESCRIPTION
1	Joint	[illegible]	[illegible]
2	Joint	[illegible]	[illegible]
3	[illegible]		[illegible]
			[illegible] N75E [illegible]

REMARKS: Tunnel Alignment - N 43°24'45"E.
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
[illegible] 1 and 2.
[illegible] "A" [illegible]

SCALE 1" = 10'

Geology By
Drawn By
Checked By
Date

US Army Corps of Engineers

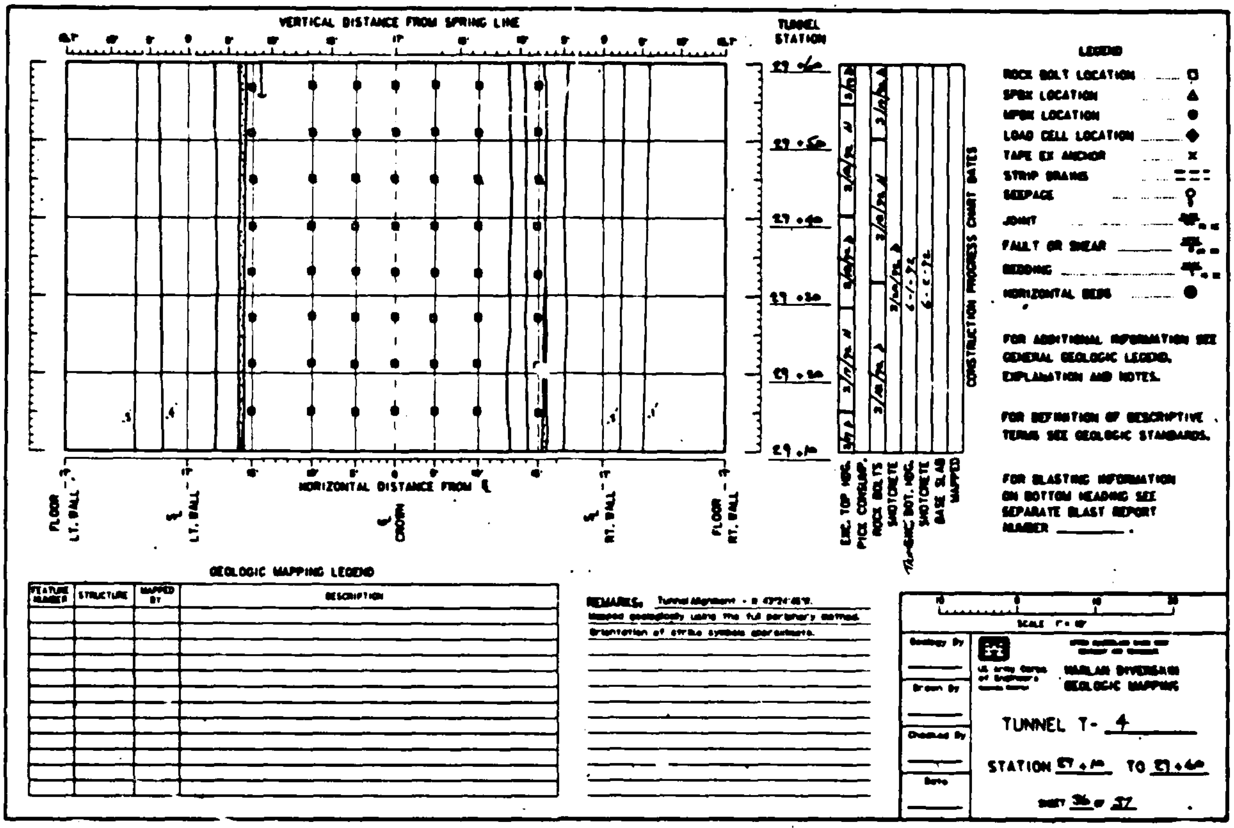
HARLAN DIVERSION GEOLOGIC MAPPING

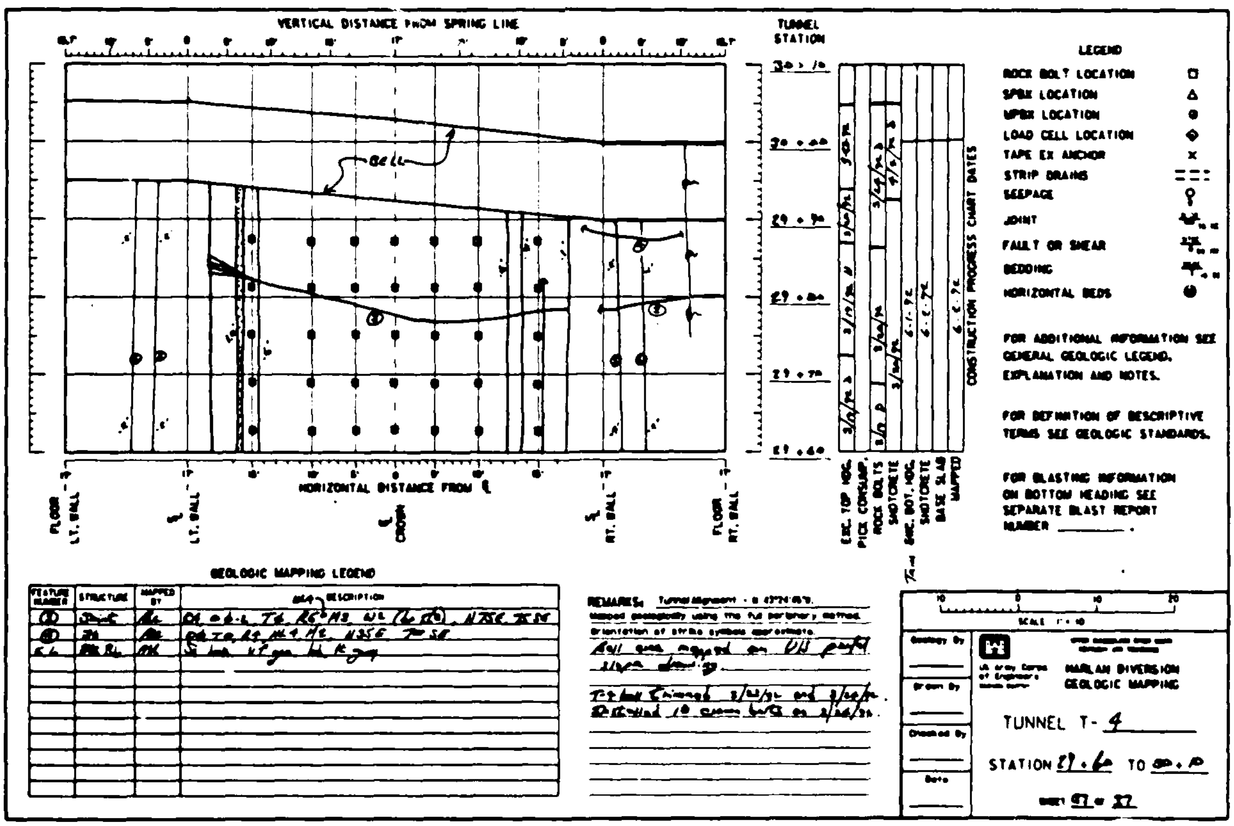
TUNNEL T- 4

STATION 28+60 TO 29+10

SHEET 35 of 37

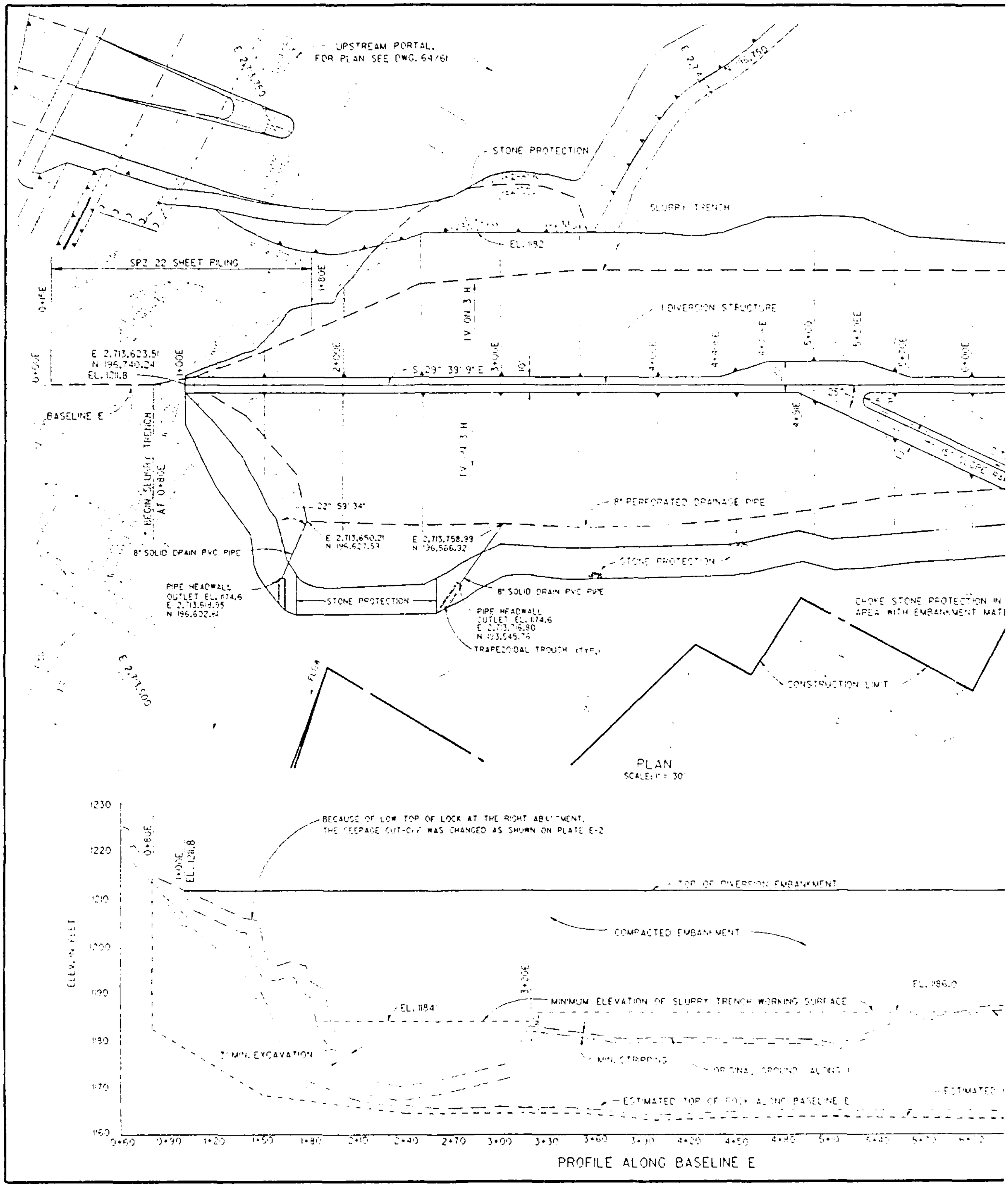
PLATE D-84


VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
29+60
29+50
29+40
29+30
29+20
29+10
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR RT. WALL
EXC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
EXC. BOT. HDG.
SHOTCRETE
BASE SLAB
MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
SCALE
Geology By
Drawn By
Checked By
Date
US Army Corps of Engineers
MARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 4
STATION 29+10 TO 29+60

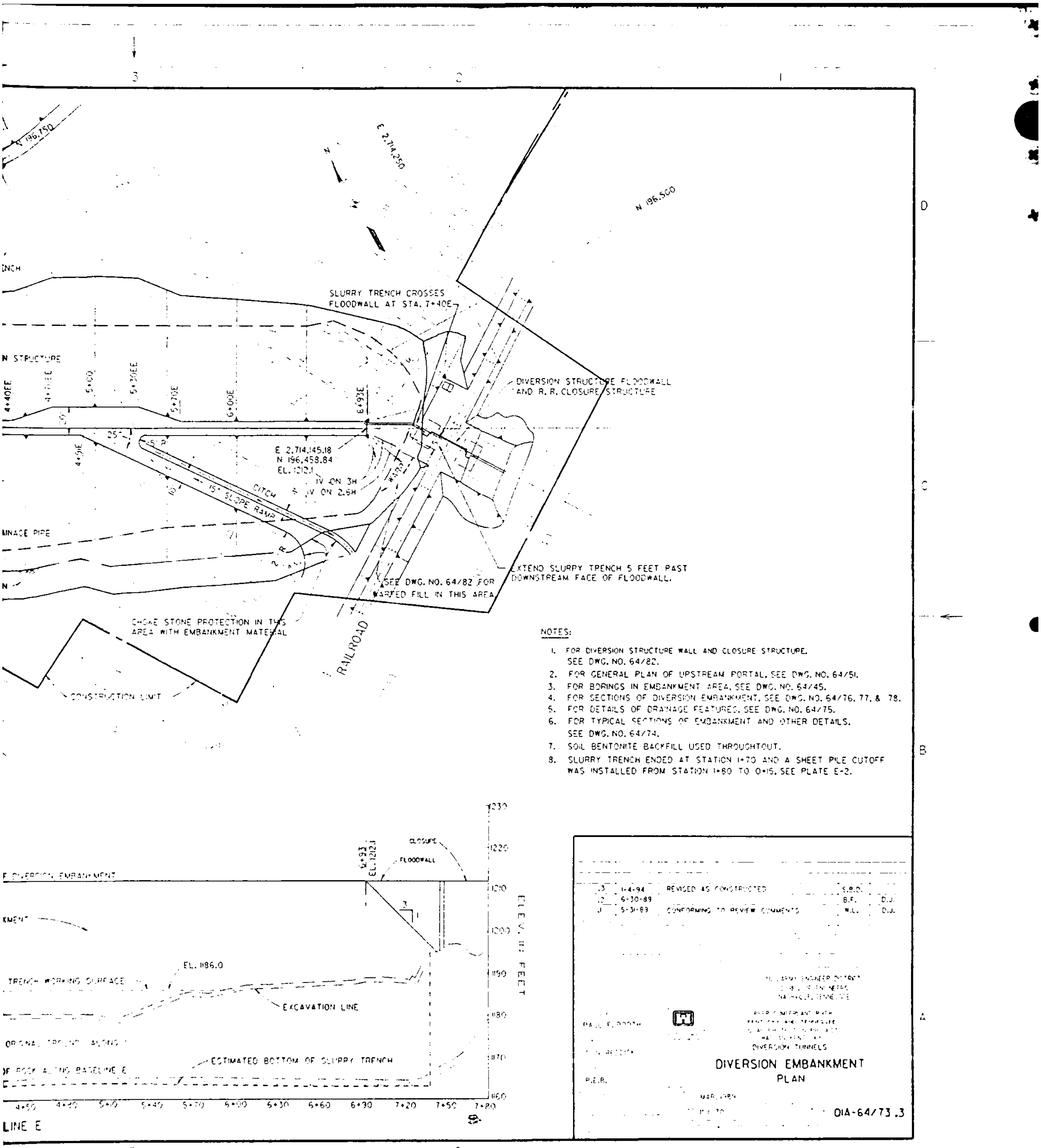

VERTICAL DISTANCE FROM SPRING LINE
TUNNEL STATION
30+10
29+90
29+80
29+70
29+60
BELL
HORIZONTAL DISTANCE FROM ℄
FLOOR LT. WALL
LT. WALL
CROWN
RT. WALL
FLOOR RT. WALL
EXC. TOP HDG.
PICK CONSUMP.
ROCK BOLTS
SHOTCRETE
SHOTCRETE
BASE SLAB
MAPPED
CONSTRUCTION PROGRESS CHART DATES
LEGEND
ROCK BOLT LOCATION
SPBX LOCATION
MPBX LOCATION
LOAD CELL LOCATION
TAPE EX ANCHOR
STRIP DRAINS
SEEPAGE
JOINT
FAULT OR SHEAR
BEDDING
HORIZONTAL BEDS
FOR ADDITIONAL INFORMATION SEE GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES.
FOR DEFINITION OF DESCRIPTIVE TERMS SEE GEOLOGIC STANDARDS.
FOR BLASTING INFORMATION ON BOTTOM HEADING SEE SEPARATE BLAST REPORT NUMBER
GEOLOGIC MAPPING LEGEND
FEATURE NUMBER
STRUCTURE
MAPPED BY
DESCRIPTION
REMARKS:
Mapped geologically using the full periphery method.
Orientation of strike symbols approximate.
SCALE
Geology By
Drawn By
Checked By
Date
US Army Corps of Engineers
MARLAN DIVERSION
GEOLOGIC MAPPING
TUNNEL T- 4
STATION 29.60 TO 30.10

Appendix E - Diversion Embankment and Slurry Trench

Plate No.	Drawing No.	Description
E-1	Q1A-64/73.3	Plan
E-2	Q1A-4/397	Seepage Cutoff Section
E-3	------	Piling Records
E-4	Q1A-64/74.3	Embankment Details
E-5	Q1A-64/45.1	Boring Plan
E-6	Q1A-64/46.1	Embankment Sections
E-7	Q1A-4/401	Boring Logs
E-8	------	Slurry Trench Backfill Borrow Site
E-9	------	Slurry Trench Backfill Gradations
E-10	------	Slurry Trench Backfill Gradations
E-11	------	Embankment Fill Compaction Tests
E-12	------	Water Line Relocation

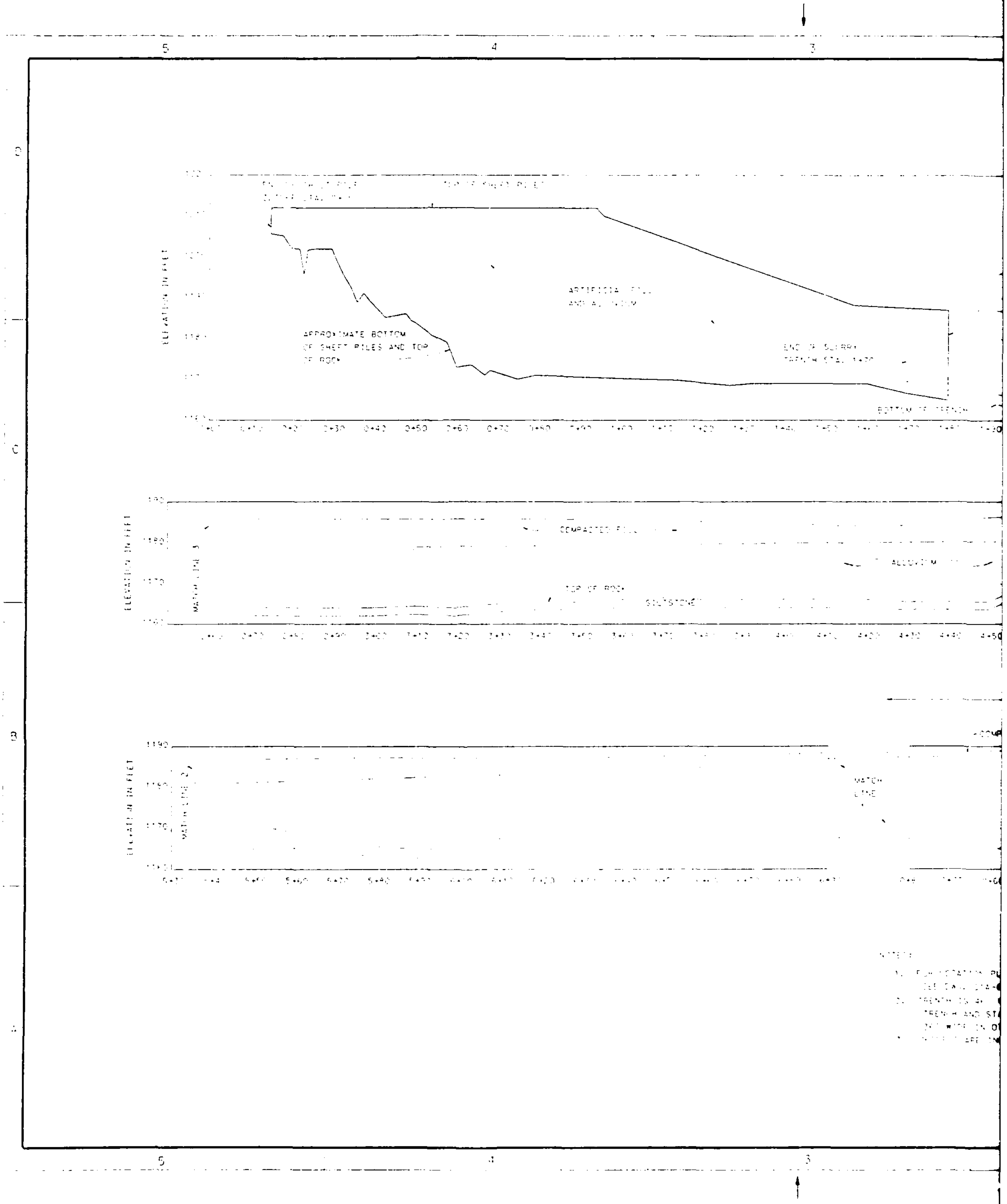


UPSTREAM PORTAL, FOR PLAN SEE DWG. 64/61
STONE PROTECTION
SLURRY TRENCH
EL. 1192
SPZ 22 SHEET PILING
DIVERSION STRUCTURE
E 2,713,623.51
N 196,740.24
EL. 1211.8
BASELINE E
BEGIN SLURRY TRENCH AT 0+80E
8" PERFORATED DRAINAGE PIPE
8" SOLID DRAIN PVC PIPE
E 2,713,650.21
N 196,627.53
E 2,713,758.39
N 196,566.32
PIPE HEADWALL
OUTLET EL. 1174.6
STONE PROTECTION
8" SOLID DRAIN PVC PIPE
TRAPEZOIDAL TROUGH (TYP.)
CHOKE STONE PROTECTION IN AREA WITH EMBANKMENT MATE
CONSTRUCTION LIMIT
FLOW
PLAN
BECAUSE OF LOW TOP OF LOCK AT THE RIGHT ABUTMENT, THE SEEPAGE CUT-OFF WAS CHANGED AS SHOWN ON PLATE E-2
TOP OF DIVERSION EMBANKMENT
COMPACTED EMBANKMENT
EL. 1184
MINIMUM ELEVATION OF SLURRY TRENCH WORKING SURFACE
EL. 1186.0
MIN. STRIPPING
ORIGINAL GROUND ALONG
ESTIMATED TOP OF ROCK ALONG BASELINE E
ELEVATION FEET
PROFILE ALONG BASELINE E

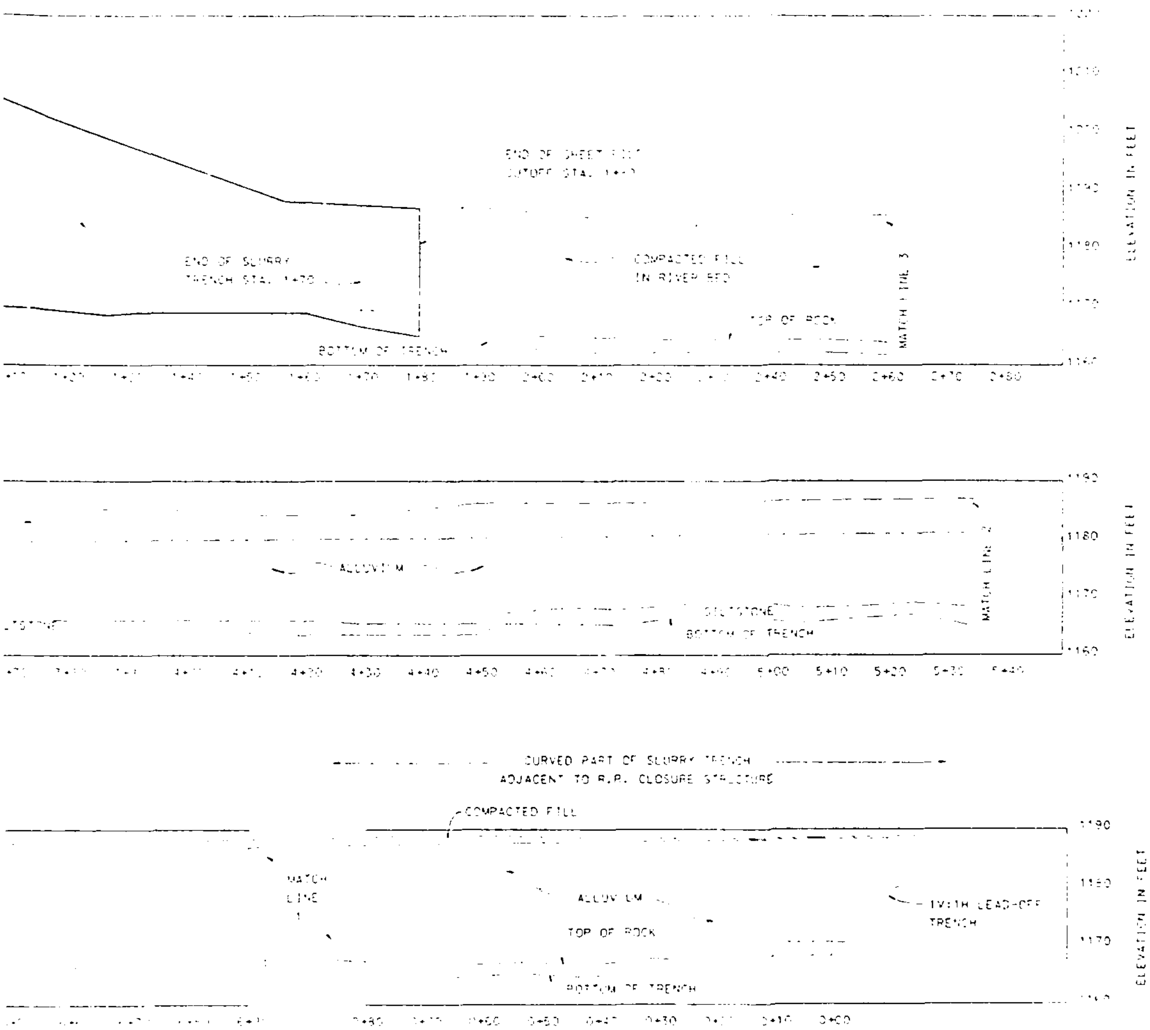


N 196,750
E 2,714,250
N 196,500
SLURRY TRENCH CROSSES FLOODWALL AT STA. 7+40E
DIVERSION STRUCTURE FLOODWALL AND R. R. CLOSURE STRUCTURE
E 2,714,145.18
N 196,458.84
EL. 1212.1
1V ON 3H
1V ON 2.6H
DITCH
15' SLOPE RAMP
EXTEND SLURRY TRENCH 5 FEET PAST DOWNSTREAM FACE OF FLOODWALL.
SEE DWG. NO. 64/82 FOR WASTED FILL IN THIS AREA
CHOKE STONE PROTECTION IN THIS AREA WITH EMBANKMENT MATERIAL
RAILROAD
CONSTRUCTION LIMIT
NOTES:
1. FOR DIVERSION STRUCTURE WALL AND CLOSURE STRUCTURE. SEE DWG. NO. 64/82.
2. FOR GENERAL PLAN OF UPSTREAM PORTAL. SEE DWG. NO. 64/51.
3. FOR BORINGS IN EMBANKMENT AREA. SEE DWG. NO. 64/45.
4. FOR SECTIONS OF DIVERSION EMBANKMENT. SEE DWG. NO. 64/76, 77, & 78.
5. FOR DETAILS OF DRAINAGE FEATURES. SEE DWG. NO. 64/75.
6. FOR TYPICAL SECTIONS OF EMBANKMENT AND OTHER DETAILS. SEE DWG. NO. 64/74.
7. SOIL BENTONITE BACKFILL USED THROUGHTOUT.
8. SLURRY TRENCH ENDED AT STATION 1+70 AND A SHEET PILE CUTOFF WAS INSTALLED FROM STATION 1+60 TO 0+15. SEE PLATE E-2.
CLOSURE
FLOODWALL
EL. 1186.0
EXCAVATION LINE
ESTIMATED BOTTOM OF SLURRY TRENCH
ELEV. IN FEET
LINE E
.3 1-4-94 REVISED AS CONSTRUCTED S.B.D.
.2 6-30-89 B.F. D.J.
.1 5-31-83 CONFORMING TO REVIEW COMMENTS W.L. D.J.
DIVERSION TUNNELS
DIVERSION EMBANKMENT
PLAN
P.E.B.
OIA-64/73 .3

PLATE E-1



APPROXIMATE BOTTOM
OF SHEET PILES AND TOP
OF ROCK
COMPACTED FILL
TOP OF ROCK
MATCH
LINE
ELEVATION IN FEET



NOTES:

1. FOR LOCATION PLAN OF SLURRY TRENCH SEE DWG. Q1A-64 (T.1 PLATE).
2. TRENCH IS 40' WIDE FROM LEAD-OFF TRENCH AND STA.0+00 TO STA.0+72. 30' WIDE IN OTHER AREAS.
3. ... ARE INCLUDED IN APPENDIX E.

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

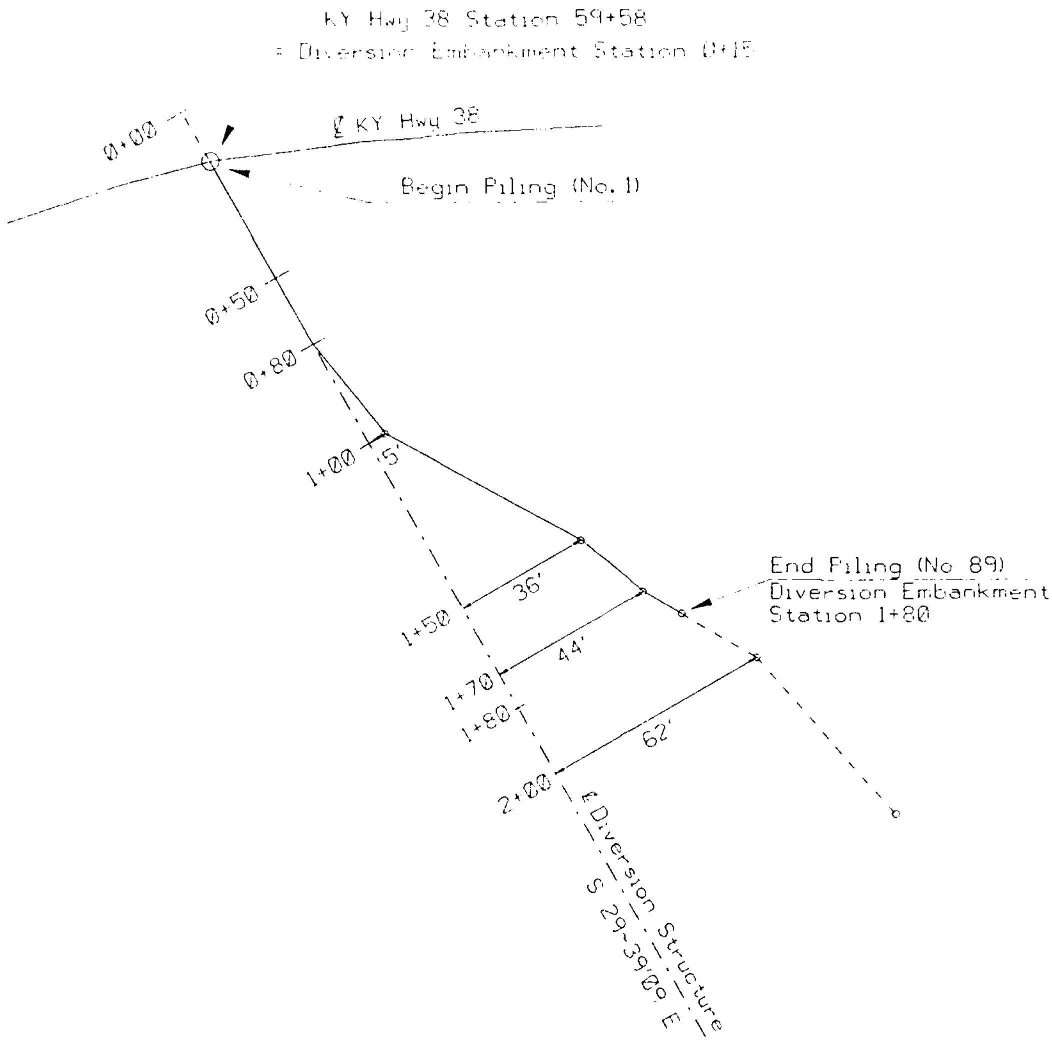
Drawn By: J.A.G.
Checked By: P.R.

UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY

DIVERSION TUNNELS

CROSS SECTION ALONG ℄ OF SLURRY TRENCH

Drawing Number: Q1A-4397



PLAN VIEW

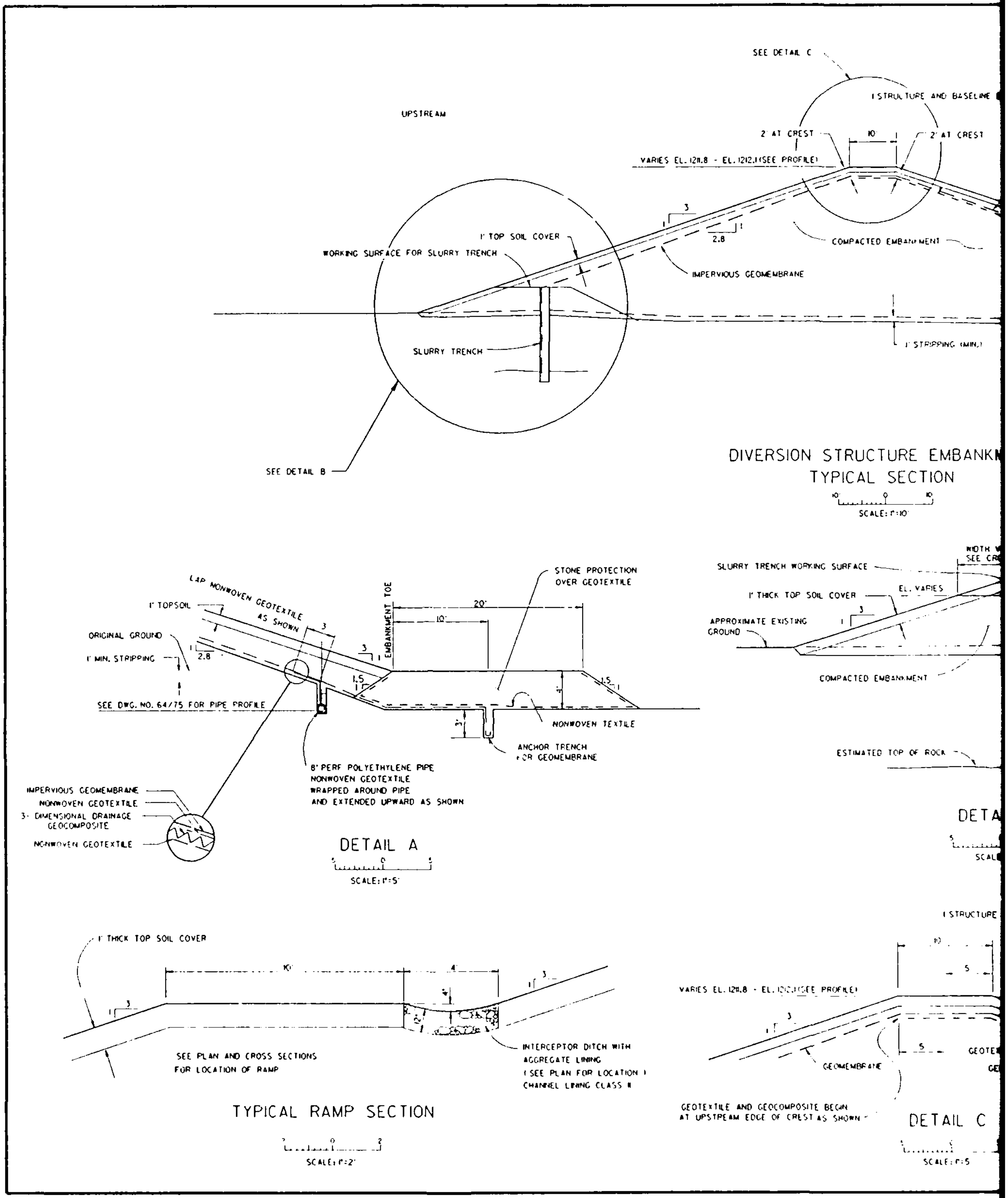
1"=20'-0"

[illegible]

	U.S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS NASHVILLE, TENNESSEE
Drawn By: SAAM	HARLAN DIVERSION PROJECT AS CONSTRUCTED DIVERSION EMBANKMENT SHEET PILING MODIFICATION PILING LOCATION and RECORDS
Checked By:	
Approved By:	Date: JAN 1994 Record drawing as constructed dated

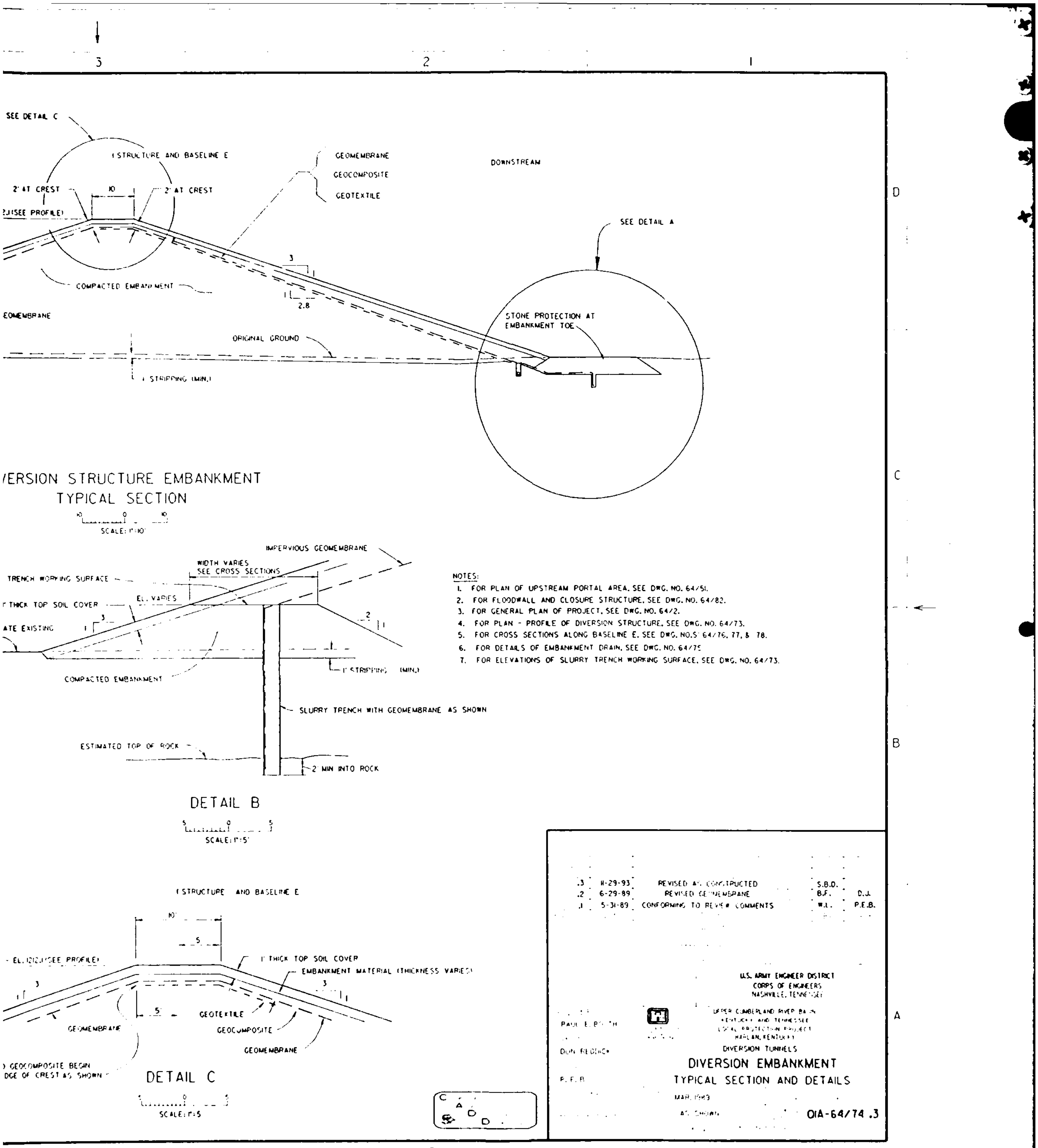
PLATE E-3

5 4 3



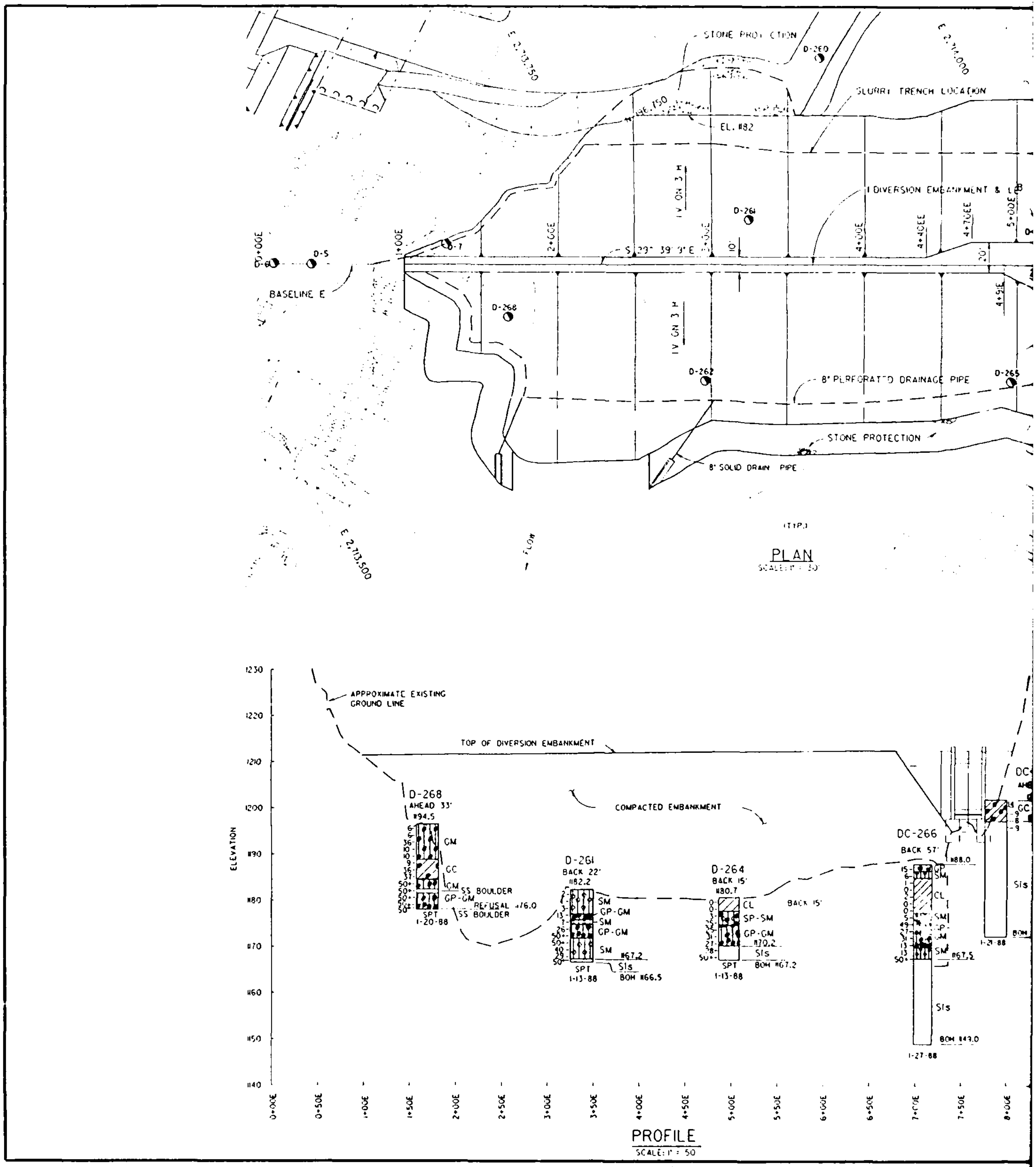
SEE DETAIL C
℄ STRUCTURE AND BASELINE
UPSTREAM
2' AT CREST
10'
2' AT CREST
VARIES EL. 1211.8 - EL. 1212.1 (SEE PROFILE)
3
1
2.8
COMPACTED EMBANKMENT
1' TOP SOIL COVER
WORKING SURFACE FOR SLURRY TRENCH
IMPERVIOUS GEOMEMBRANE
SLURRY TRENCH
1' STRIPPING (MIN.)
SEE DETAIL B
DIVERSION STRUCTURE EMBANK
TYPICAL SECTION
SCALE: 1"=10'
LAP NONWOVEN GEOTEXTILE AS SHOWN
1' TOPSOIL
ORIGINAL GROUND
1' MIN. STRIPPING
EMBANKMENT TOE
20'
10'
STONE PROTECTION OVER GEOTEXTILE
1.5
SEE DWG. NO. 64/75 FOR PIPE PROFILE
NONWOVEN TEXTILE
ANCHOR TRENCH FOR GEOMEMBRANE
8" PERF POLYETHYLENE PIPE
NONWOVEN GEOTEXTILE
WRAPPED AROUND PIPE
AND EXTENDED UPWARD AS SHOWN
IMPERVIOUS GEOMEMBRANE
NONWOVEN GEOTEXTILE
3- DIMENSIONAL DRAINAGE GEOCOMPOSITE
NONWOVEN GEOTEXTILE
DETAIL A
SCALE: 1"=5'
SLURRY TRENCH WORKING SURFACE
WIDTH V
SEE CR
EL. VARIES
1' THICK TOP SOIL COVER
APPROXIMATE EXISTING GROUND
COMPACTED EMBANKMENT
ESTIMATED TOP OF ROCK
DETA
SCAL
1' THICK TOP SOIL COVER
10'
4'
SEE PLAN AND CROSS SECTIONS FOR LOCATION OF RAMP
INTERCEPTOR DITCH WITH AGGREGATE LINING
(SEE PLAN FOR LOCATION)
CHANNEL LINING CLASS II
TYPICAL RAMP SECTION
SCALE: 1"=2'
℄ STRUCTURE
VARIES EL. 1211.8 - EL. 1212.1 (SEE PROFILE)
GEOMEMBRANE
GEOTE
GEOTEXTILE AND GEOCOMPOSITE BEGIN AT UPSTREAM EDGE OF CREST AS SHOWN
DETAIL C
SCALE: 1"=5'

5 4 3

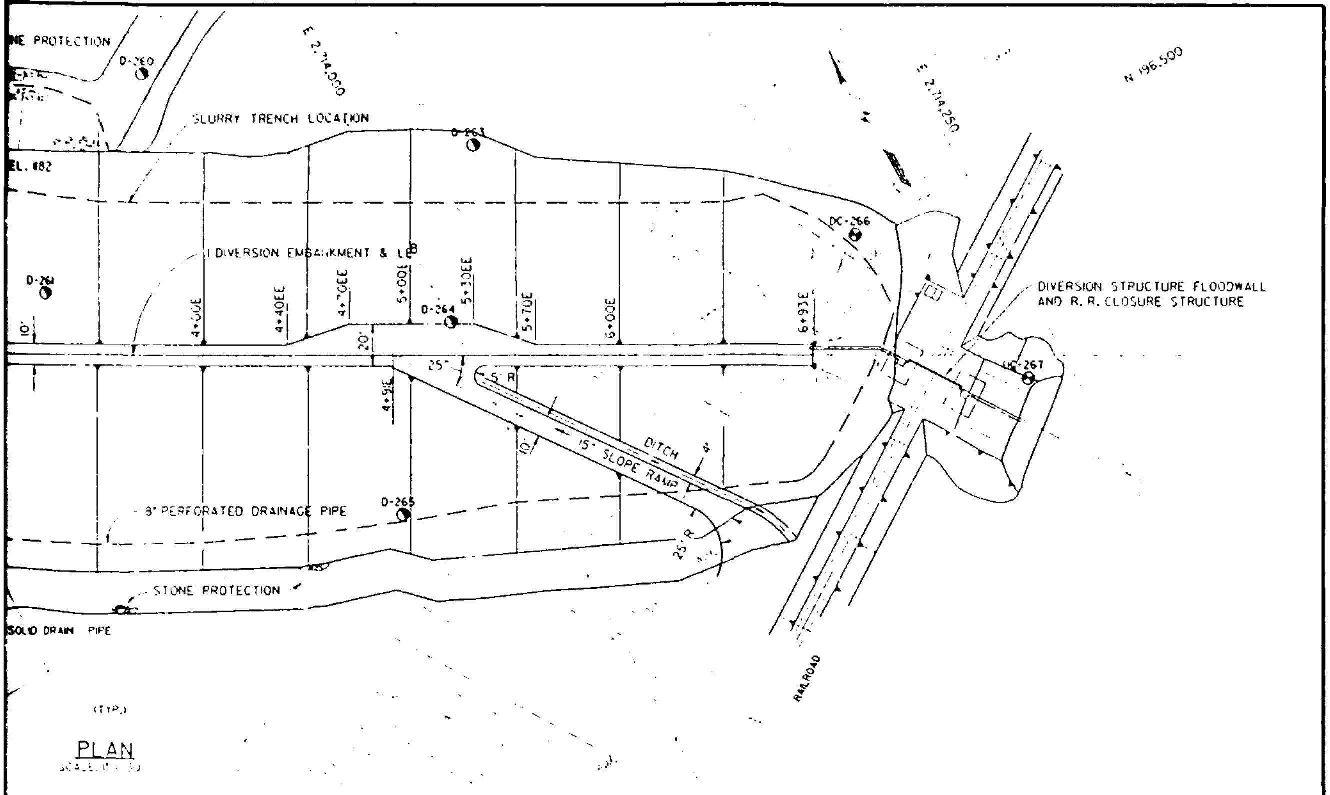


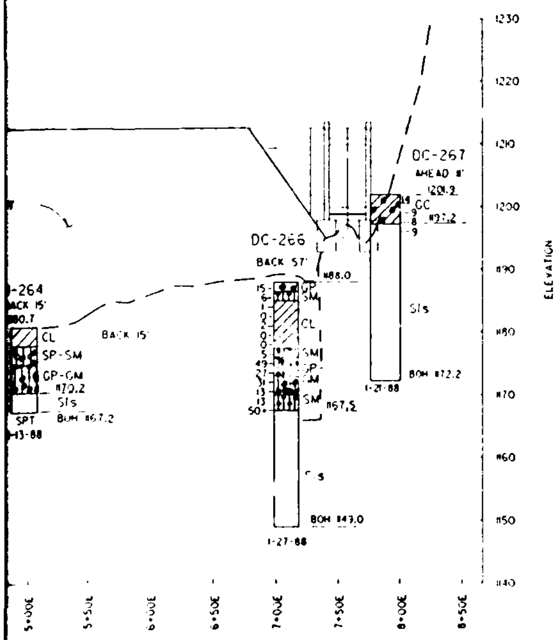
SEE DETAIL C
℄ STRUCTURE AND BASELINE E
2' AT CREST
10
2' AT CREST
(SEE PROFILE)
GEOMEMBRANE
GEOCOMPOSITE
GEOTEXTILE
DOWNSTREAM
SEE DETAIL A
3
1
1
2.8
COMPACTED EMBANKMENT
GEOMEMBRANE
STONE PROTECTION AT EMBANKMENT TOE
ORIGINAL GROUND
1' STRIPPING (MIN.)
DIVERSION STRUCTURE EMBANKMENT
TYPICAL SECTION
SCALE: 1"=10'
IMPERVIOUS GEOMEMBRANE
WIDTH VARIES
SEE CROSS SECTIONS
TRENCH WORKING SURFACE
EL. VARIES
1' THICK TOP SOIL COVER
2
1
COMPACTED EMBANKMENT
1' STRIPPING (MIN.)
SLURRY TRENCH WITH GEOMEMBRANE AS SHOWN
ESTIMATED TOP OF ROCK
2 MIN INTO ROCK
DETAIL B
SCALE: 1"=5'
NOTES:
1. FOR PLAN OF UPSTREAM PORTAL AREA, SEE DWG. NO. 64/51.
2. FOR FLOODWALL AND CLOSURE STRUCTURE, SEE DWG. NO. 64/82.
3. FOR GENERAL PLAN OF PROJECT, SEE DWG. NO. 64/2.
4. FOR PLAN - PROFILE OF DIVERSION STRUCTURE, SEE DWG. NO. 64/73.
5. FOR CROSS SECTIONS ALONG BASELINE E, SEE DWG. NO.S 64/76, 77, & 78.
6. FOR DETAILS OF EMBANKMENT DRAIN, SEE DWG. NO. 64/75
7. FOR ELEVATIONS OF SLURRY TRENCH WORKING SURFACE, SEE DWG. NO. 64/73.
℄ STRUCTURE AND BASELINE E
10'
5'
EL. 1212 (SEE PROFILE)
1' THICK TOP SOIL COVER
EMBANKMENT MATERIAL (THICKNESS VARIES)
3
1
5'
GEOTEXTILE
GEOMEMBRANE
GEOCOMPOSITE
GEOMEMBRANE
GEOCOMPOSITE BEGIN
EDGE OF CREST AS SHOWN
DETAIL C
SCALE: 1"=5'
.3 11-29-93 REVISED AS CONSTRUCTED S.B.D.
.2 6-29-89 REVISED GEOMEMBRANE B.F. D.J.
.1 5-31-89 CONFORMING TO REVIEW COMMENTS W.L. P.E.B.
U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE
UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION TUNNELS
DIVERSION EMBANKMENT
TYPICAL SECTION AND DETAILS
MAR. 1989
AS SHOWN
OIA-64/74 .3

PLATE E-4



STONE PROTECTION
D-260
E 2,714,000
E 2,713,750
SLURRY TRENCH LOCATION
EL. 1182
DIVERSION EMBANKMENT & LE
1V ON 3 H
D-261
0+00E
D-6
D-5
D-7
1+00E
2+00E
4+00E
4+40EE
4+70EE
5+00E
BASELINE E
D-268
1V ON 3 H
D-262
8" PERFORATED DRAINAGE PIPE
D-265
STONE PROTECTION
8" SOLID DRAIN PIPE
E 2,713,500
FLOW
PLAN
APPROXIMATE EXISTING GROUND LINE
TOP OF DIVERSION EMBANKMENT
COMPACTED EMBANKMENT
ELEVATION
D-268
AHEAD 33'
1194.5
GM
GC
GM
SS BOULDER
GP-GM
REFUSAL 1176.0
SS BOULDER
SPT
1-20-88
D-261
BACK 22'
1182.2
SM
GP-GM
SM
GP-GM
SM
1167.2
SIs
BOH 1166.5
SPT
1-13-88
D-264
BACK 15'
1180.7
CL
SP-SM
GP-GM
1170.2
SIs
BOH 1167.2
SPT
1-13-88
BACK 15'
DC-266
BACK 57'
1188.0
SM
CL
SM
SM
1167.5
SIs
BOH 1143.0
1-27-88
SIs
1-21-88
GC
1230
1220
1210
1200
1190
1180
1170
1160
1150
1140
0+00E
0+50E
1+00E
1+50E
2+00E
2+50E
3+00E
3+50E
4+00E
4+50E
5+00E
5+50E
6+00E
6+50E
7+00E
7+50E
8+00E
PROFILE
SCALE: 1" = 50'





NOTES:
1. FOR GENERAL PLAN OF DIVERSION EMBANKMENT, SEE DWG. NO. 64/73.
2. FOR BORING LEGEND, SEE DWG. NO. 64/5.
3. FOR OVERALL BORING PLAN, SEE DWG. NO. 64/4.
4. FOR ADDITIONAL EXPLORATION IN UPSTREAM PORTAL, SEE DWG. NO. 64/32.
5. FOR SUBSURFACE SECTIONS THROUGH EMBANKMENT, SEE DWG. NO. 64/46.
6. GRAPHIC LOGS SHOWN ARE GENERALIZED AND SHOULD BE USED IN CONJUNCTION WITH DETAILED TESTING INFORMATION PRESENTED IN APPENDIX A OF THE SPECIFICATIONS.
7. SLURRY TRENCH CONSTRUCTED AS SHOWN ON PLATES E-1 AND E-2.

Revisions	Date	Description	By	Checked
1	2-2-94	AS CONSTRUCTED	MAP	

HORIZONTAL SCALE 50 0 50
VERTICAL SCALE 10 0 10

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

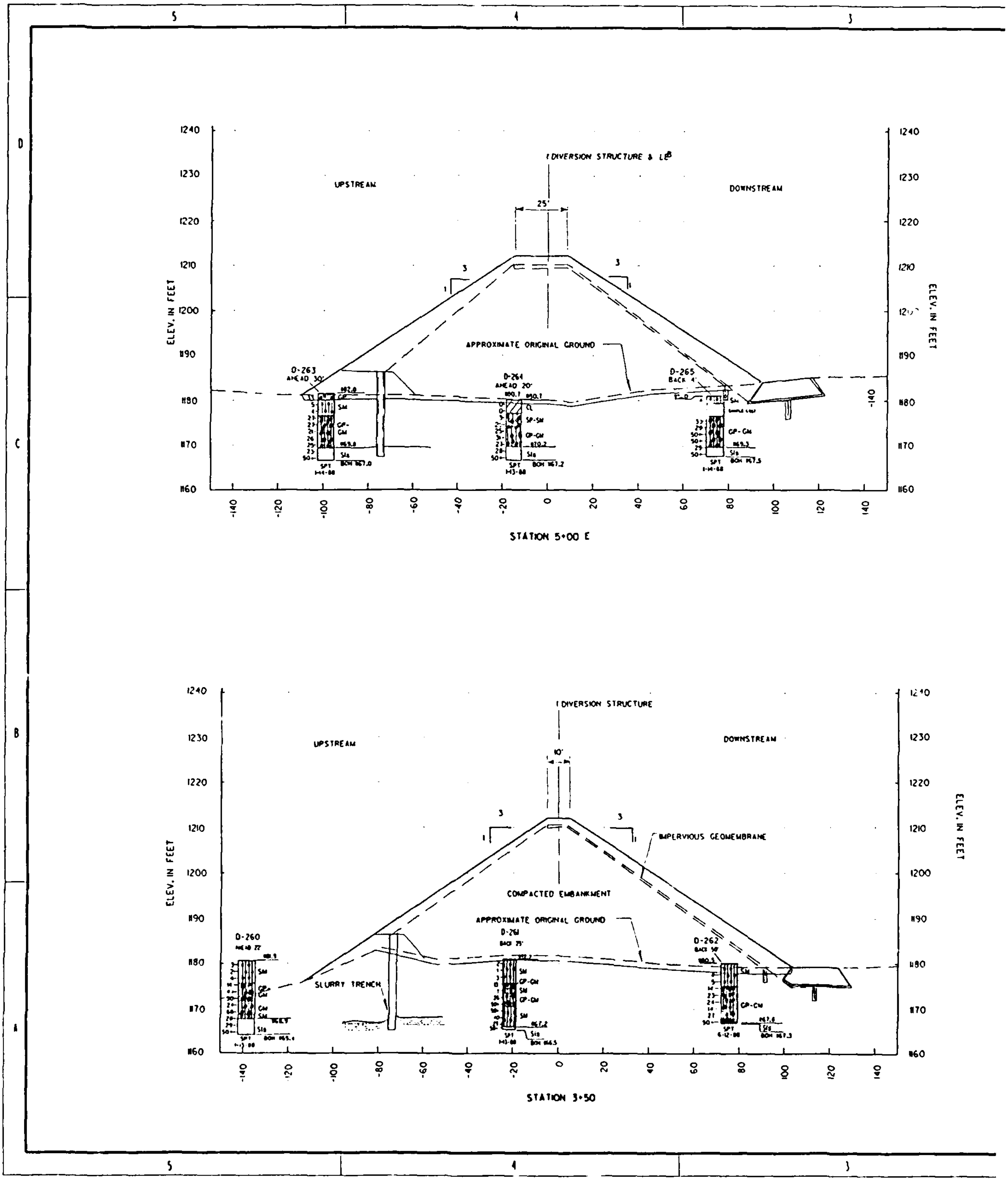
Designed By: P.E.B.
Drawn By: T. COLLINS
Checked By: P.E.B.
Approved By: CHIEF, GEOTECHNICAL BRANCH

LOWER CUMBERLAND RIVER
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION TUNNEL

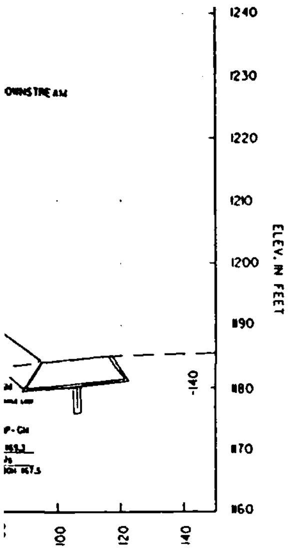
DIVERSION EMBANKMENT
BORING PLAN AND SUBSURFACE PROFILE

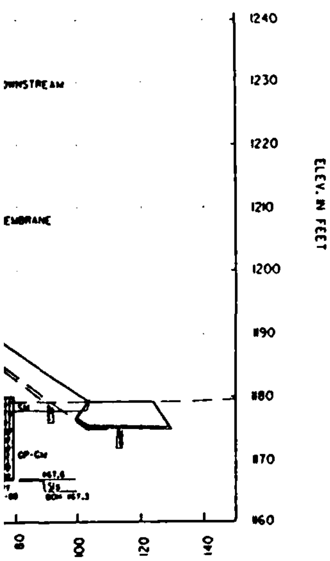
Date: FEB 1989
Scale: AS SHOWN
Sheet 1 of 2
Drawing Number: OIA-64/45.1
Record Drawing as constructed dated

PLATE E-5



DIVERSION STRUCTURE & LE
UPSTREAM
DOWNSTREAM
25'
APPROXIMATE ORIGINAL GROUND
D-263
D-264
D-265
ELEV. IN FEET
STATION 5+00 E
DIVERSION STRUCTURE
10'
IMPERVIOUS GEOMEMBRANE
COMPACTED EMBANKMENT
SLURRY TRENCH
D-260
D-261
D-262
STATION 3+50





NOTES:
1. FOR BORING PLAN OF DIVERSION EMBANKMENT, SEE DWG. NO. 64/45.
2. FOR BORING LEGEND, SEE DWG. NO. 64/5.
3. FOR OVERALL BORING PLAN, SEE DWG. NO. 64/4.
4. FOR GENERAL PLAN OF DIVERSION EMBANKMENT, SEE DWG. NO. 64/73.

Revisions	Date	Description	By	Checked
.1	1-94	REVISED AS-CONSTRUCTED	MAR	

H SCALE: 1" = 20'
V SCALE: 1" = 10'
Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION TUNNELS

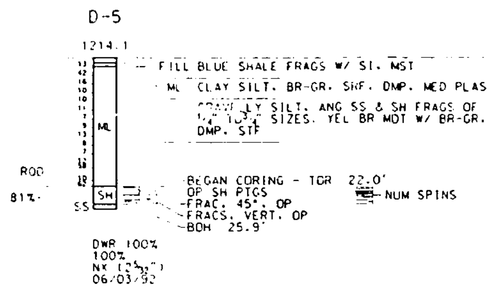
DIVERSION EMBANKMENT
SUBSURFACE SECTIONS

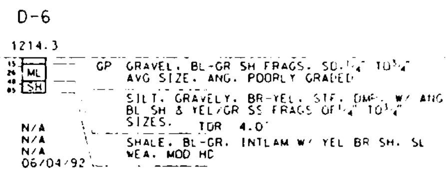
Designed By: Paul C. Booth
Drawn By: T. COLLINS
Checked By: P.E.B.
Approved By: CHIEF, GEOTECHNICAL BRANCH
FILE:

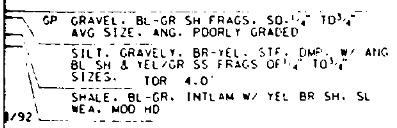
Date: FEB 1989
SHEET 2 OF 2
Scale: 1" = 20' H 1"=10' V
Drawing Number OIA-64/46.1
Record Drawing as constructed dated

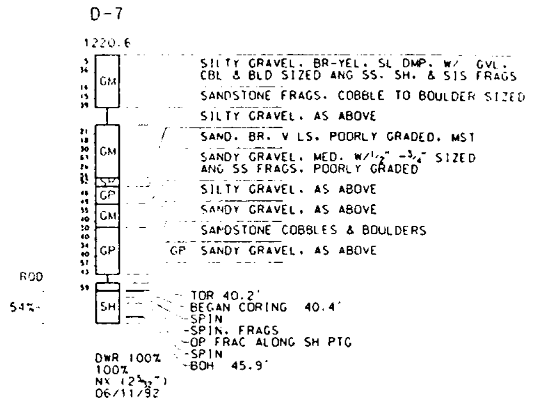
COMPUTER AIDED DESIGN & DRAFTING SOILS SECTION

PLATE E-6


D-5
1214.1
FILL BLUE SHALE FRAGS W/ SI. MST
ML CLAY SILT. BR-GR. SKF. DMP. MED PLAS
SILT. ANG SS & SH FRAGS OF
SIZES. YEL BR MDT W/ BR-GR.
DMP. STF
ML
ROD
81%
SH
SS
BEGAN CORING - TOR 22.0'
OP SH PTGS
NUM SPINS
FRAC. 45°. OP
FRACS. VERT. OP
BOH 25.9'
DWR 100%
100%
06/03/92


D-6
1214.3
ML
SH
GP GRAVEL. BL-GR SH FRAGS.
AVG SIZE. ANG. POORLY GRADED
SILT. GRAVELY. BR-YEL. STF.
BL SH & YEL/GR SS FRAGS
SIZES.
TOR 4.0'
N/A
N/A
N/A
06/04/92
SHALE. BL-GR. INTLAM W/ YEL BR SH. SL
WEA. MOD HC





NOTES:

1. SEE PLATE A-2 FOR ABBREVIATIONS.
2. SEE PLATES A-3 THRU A-5 FOR DEFINATIONS AND DESCRIPTIVE TERMS.
3. SEE PLATE H-2 FOR BORING LOCATION PLAN.

Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

Drawn By: R.U.

Checked By: P.R.

P.R.
GEOLOGIST

Approved By:

CHIEF, GEOTECHNICAL BRANCH

CHIEF, ENGINEERING DIVISION

UPPER CUMBERLAND RIVER BASIN

LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY

LOGS OF BORINGS

DIVERSION DAM RIGHT ABUTMENT

Date: DECEMBER 1992

Scale: AS SHOWN

Revised Drawing as constructed dated

Drawing Number **Q1A-4/401**

COMPUTER AIDED DESIGN & DRAFTING
GEOLOGY SECTION

PLATE E-7

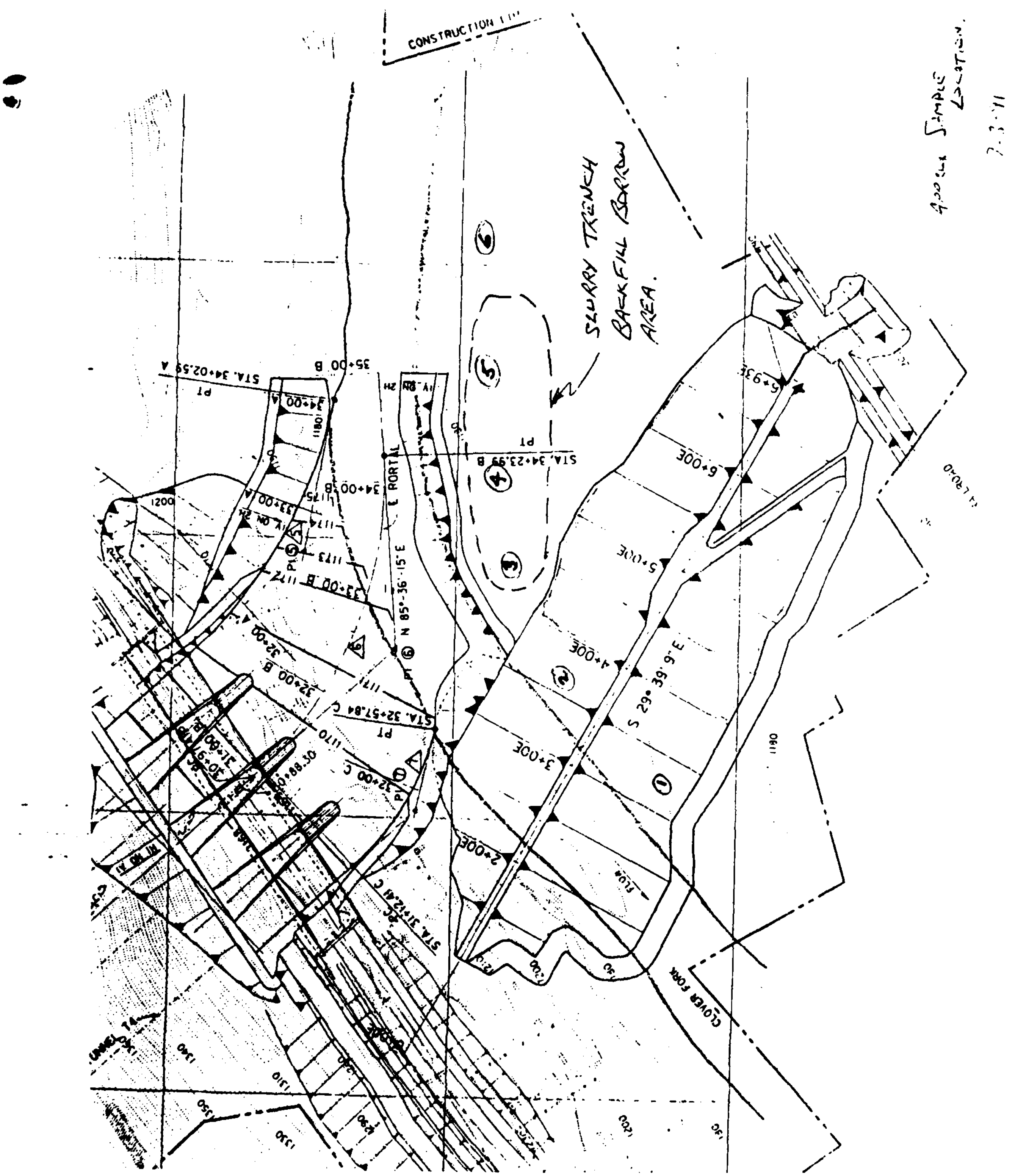

CONSTRUCTION LIMIT
SLURRY TRENCH BACKFILL BORROW AREA.
Approx Sample Location.
STA. 34+02.59 A
STA. 34+23.99 B
STA. 32+57.84 C
STA. 31+12.41 C
N 85°-36'-15" E
S 29° 39' 9" E
℄ PORTAL
CLOVER FORK
2+00E
3+00E
4+00E
5+00E
6+00E
6+93E

PLATE E-8

PLATE E-9

U.S ARMY ENGINEER DISTRICT, NASHVILLE
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

AGGREGATE TEST REPORT

Project: Harlan Diversion
Approved: /
Rejected:

SIEVES	WEIGHT RETAINED	PER CENT RETAINED	ACCUMULATIVE RETAINED	PER CENT PASSING	TEST RESULTS (SPECS)	
					F.M.	
					SOFTS	
					DELETERIOUS	
					COLOR	
					SILT	
					WT./CU.FT.	
6"	0.0	0.0	0.0	100.0	SP.GR.	100
3"	0.0	0.0	0.0	100.0	VOIDS	95-100
#4	38.1	15.0	15.0	85.0		50-100
#40	45.6	18.0	33.0	67.0		30-80
#200	115.0	45.5	78.5	21.5		15-25
PAN	54.3	21.5	100.0			
TOTAL	253.0	100.0				

REMARKS:
#3

DISPOSITION: Mat for soil Bentonite
LOCATION: See Attachment
SAMPLE NO. 3 of 6
DATE: 3-Sept. 91
SAMPLED: B.C.
ANALYSIS: Boswell
SOUNDNESS:
WEIGHT: 253.0

ORN Form 266 Constr. Div. CEORN-CD

U.S ARMY ENGINEER DISTRICT, NASHVILLE
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

AGGREGATE TEST REPORT

Project: Harlan Diversion
Approved: /
Rejected:

SIEVES	WEIGHT RETAINED	PER CENT RETAINED	ACCUMULATIVE RETAINED	PER CENT PASSING	TEST RESULTS (SPECS)	
					F.M.	
					SOFTS	
					DELETERIOUS	
					COLOR	
					SILT	
					WT./CU.FT.	
6"	0.0	0.0	0.0	100.0	SP.GR.	100
3"	0.0	0.0	0.0	100.0	VOIDS	95-100
#4	32.7	10.2	10.2	89.8		50-100
#10	46.6	14.5	24.7	75.3		30-80
#200	169.5	52.6	77.3	22.7		15-25
PAN	73.3	22.7	100.0			
TOTAL	322.1	100.0				

REMARKS:
#4

DISPOSITION: Mat. of soil Bentonite
LOCATION: See Attachment
SAMPLE NO. 4 of 6
DATE: 3-Sept 1991
SAMPLED: O.C.
ANALYSIS: Boswell
SOUNDNESS:
WEIGHT: 322.1

ORN Form 266 Constr. Div. CEORN-CD

U.S ARMY ENGINEER DISTRICT, NASHVILLE
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

AGGREGATE TEST REPORT

Project: Harlan Diversion
Approved: ✓
Rejected:

SIEVES	WEIGHT RETAINED	PER CENT RETAINED	ACCUMULATIVE RETAINED	PER CENT PASSING	TEST RESULTS (SPECS)	
					F.M.	
					SOFTS	
					DELETERIOUS	
					COLOR	
					SILT	
					WT./CU.FT.	
6"	0.0	0.0	0.0	100.0	SP.GR.	100
3"	0.0	0.0	0.0	100.0	VOIDS	95-100
#4	135.3	38.4	38.4	61.6		50-100
#40	43.4	12.3	50.7	49.3		30-80
#200	108.1	30.6	81.3	18.7		15-25
PAN	65.5	18.7	100.0			
TOTAL	352.3	100.0				

REMARKS:
#5

DISPOSITION: Mat. for soil Bentonite | LOCATION: See Attachment
SAMPLE NO. 5 of 6 | DATE: 3-Sept 91
SAMPLED: O.C | ANALYSIS: Boswell | SOUNDNESS: | WEIGHT: 352.3

266 | Constr. Div. CEORN-CD

U.S ARMY ENGINEER DISTRICT, NASHVILLE
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

AGGREGATE TEST REPORT

Project: Harlan Diversion
Approved: ✓
Rejected:

SIEVES	WEIGHT RETAINED	PER CENT RETAINED	ACCUMULATIVE RETAINED	PER CENT PASSING	TEST RESULTS (SPECS)	
					F.M.	
					SOFTS	
					DELETERIOUS	
					COLOR	
					SILT	
					WT./CU.FT.	
6"	0.0	0.0	0.0	100.0	SP.GR.	100
3"	0.0	0.0	0.0	100.0	VOIDS	~~100~~ 95-100
#4	91.1	26.6	26.6	73.4		~~95-100~~ 50-100
#40	38.5	11.3	37.9	62.1		~~50-100~~ 30-80
#200	146.2	42.8	80.7	19.3		~~30-80~~ 15-25
PAN	65.6	19.3	100.0			
TOTAL	341.4	100.0				

REMARKS:
#6

DISPOSITION: Mat. for soil Bentonite | LOCATION: See Attachment
SAMPLE NO. 6 of 6 | DATE: 3-Sept 91
SAMPLED: O.C | ANALYSIS: Boswell | SOUNDNESS: | WEIGHT: 341.4

ORN Form 266 | Constr. Div. CEORN-CD

U.S. ARMY ENGINEER DISTRICT, NASHVILLE
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

NUCLEAR COMPACTION
TEST DATA

PROJECT: H. W. Kogueth

JOB NO.:

DATE: 16 - Jan 1992

TAKEN BY: Boswell

TEST NUMBER	1	2	3	4	5	6
STATION	5+80	5+50	5+00			
OFFSET	Rt. 10' of ℄ Levee	20' Lt ℄ of Levee	Lt. 15' of Levee ℄			
ELEVATION	7' Above Slurry T.	7' Above Slurry T.	7' Above Slurry T.			
SOURCE	Levee Fill	Levee Fill	Levee Fill			
MODE & DEPTH	8"	8"	8"			
DENS. COUNT	1028	1017	0865			
MSTRE. COUNT						
WET DENSITY	143.8	144.1	141.7			
MOISTURE	6.0	8.0	9.1			
DRY DENSITY	137.8	136.1	150.8			
% MOISTURE	4.3	5.7	6.5			
STANDARD DENS.	167.0	167.0	167.0			
OPT. MSTRE.						
% COMPACTION	82.5	81.5	84.8			
MSTRE. CORR.						
	6-passes	8-passes	8-passes			

REMARKS:

Test No. 1. Fill looked good but possibly on the dry side for best compaction.

Test No. 2 Fill was creeping and pumping due to moisture (high) under the surface.

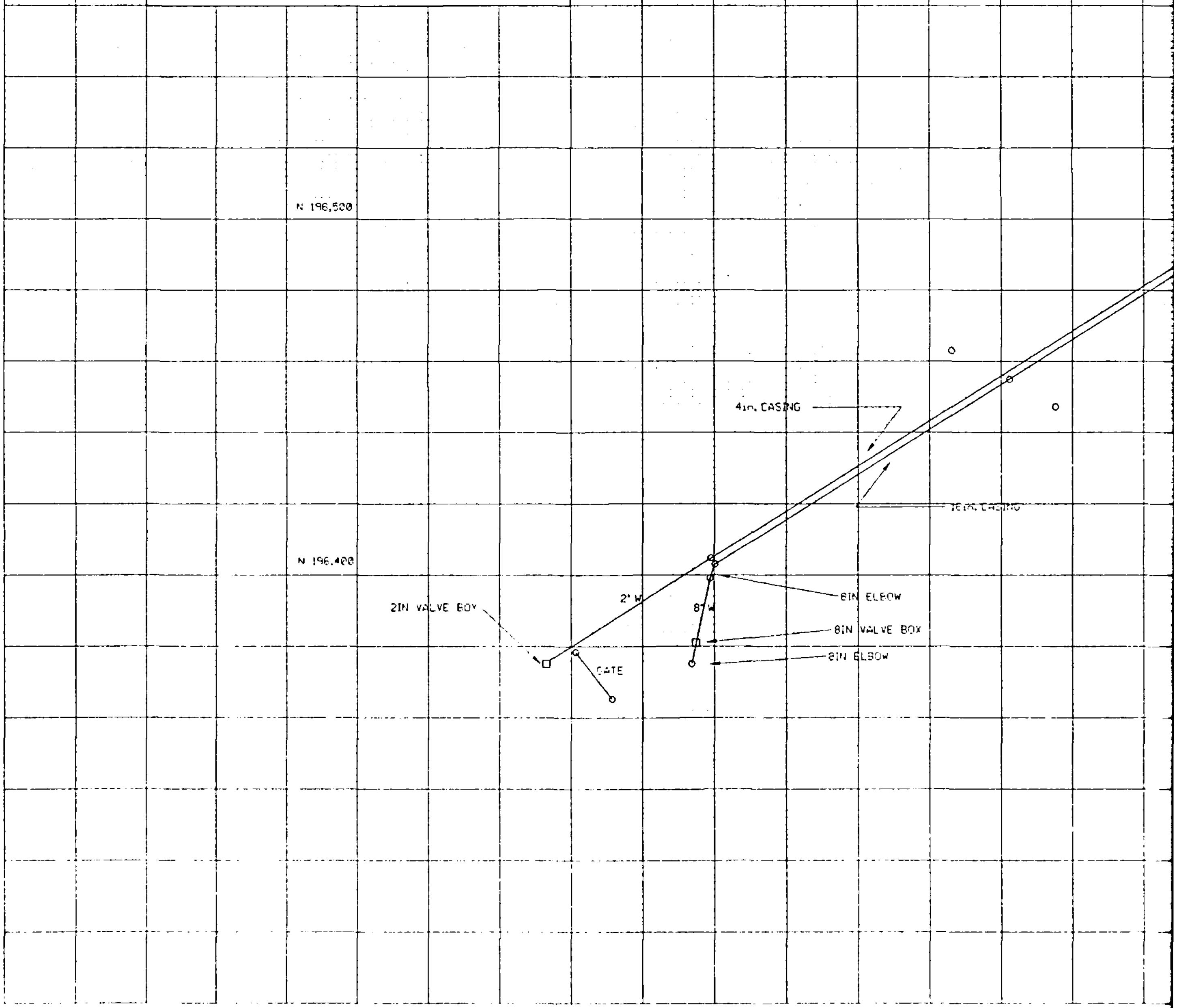
Test No. 3 Fill area had more fine material than first two. Area was soft and pumping.

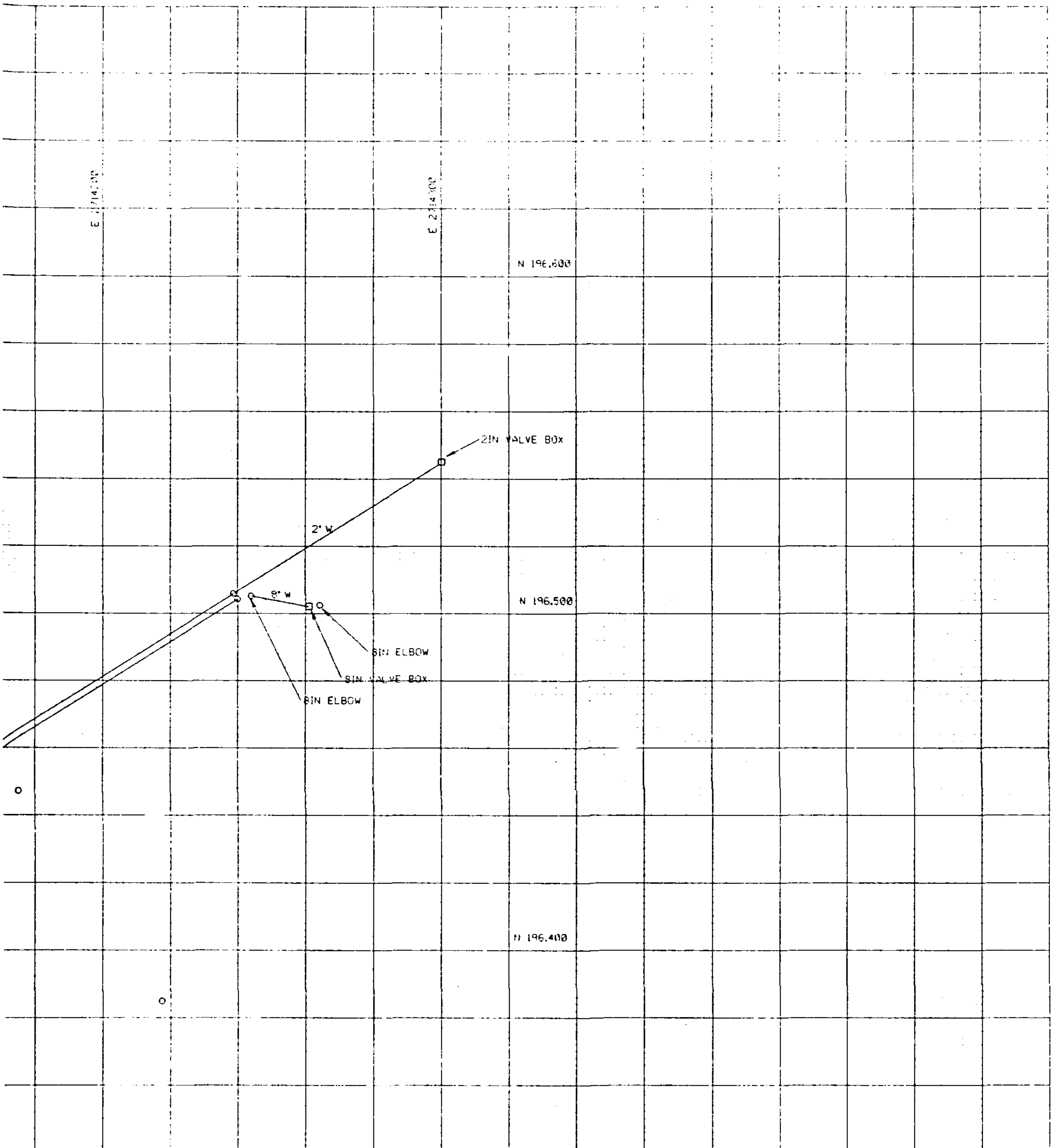
ORN FORM 548
DEC 1984

ORNCD

PLATE E-11

NORTH	EAST	ELEVATION	REMARKS
196,503.58	2,714,233.15	1184.73	TOP OF 16" CASTING EAST END
196,400.67	2,714,073.91	1185.32	TOP OF 16" CASTING WEST END
196,505.56	2,714,236.24	1183.78	TOP OF 4" CASTING-EAST END
196,402.84	2,714,076.37	1184.48	TOP OF 4" CASTING-WEST END
196,454.[illegible]	2,714,[illegible].29	1184.90	PIPE CROSSING [illegible] WALL
196,5[illegible]	2,714,241.[illegible]	1184.2[illegible]	ELBOW EAST END [illegible]
196,500.6[illegible]	2,714,2[illegible].52	1184.44	ELBOW EAST END 6"
196,399.58	2,714,078.83	1184.86	ELBOW WEST END-6"
196,374.50	2,714,073.09	1185.23	ELBOW WEST END-8"
196,374.08	2,714,033.08	1189.11	8" VALVE-WEST END
196,377.80	2,714,041.30		GATE POST-NORTH EDGE ROAD
196,365.20	2,714,051.44		GATE POST-SOUTH EDGE ROAD
196,380.72	2,714,073.98	1189.98	2" VALVE-WEST END
196,502.93	2,714,260.33	1187.91	8" VALVE-EAST END
196,544.94	2,714,296.20	1188.42	2" VALVE- EAST END





U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

Drawn By: SAAA

Checked By:

ENGINEER

Approved By:

CHIEF, BRANCH

CHIEF, ENGINEERING DIVISION

HARLAN DIVERSION PROJECT
AS CONSTRUCTED
2 In. & 8 In. WATERLINE RELOCATION
HARLAN GAS ROAD at DIVERSION DAM

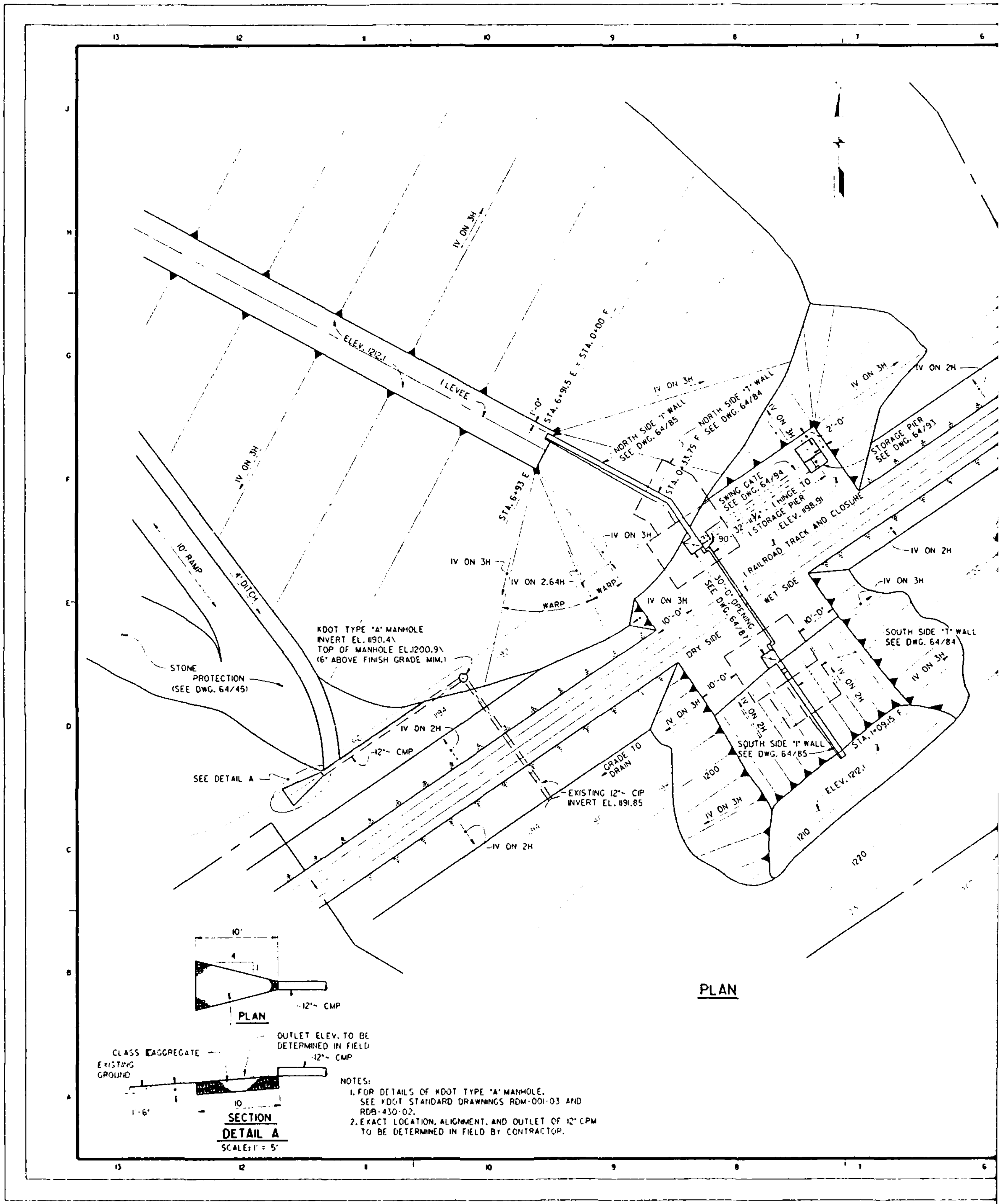
Date: JAN 1994

Record Drawing as constructed dated

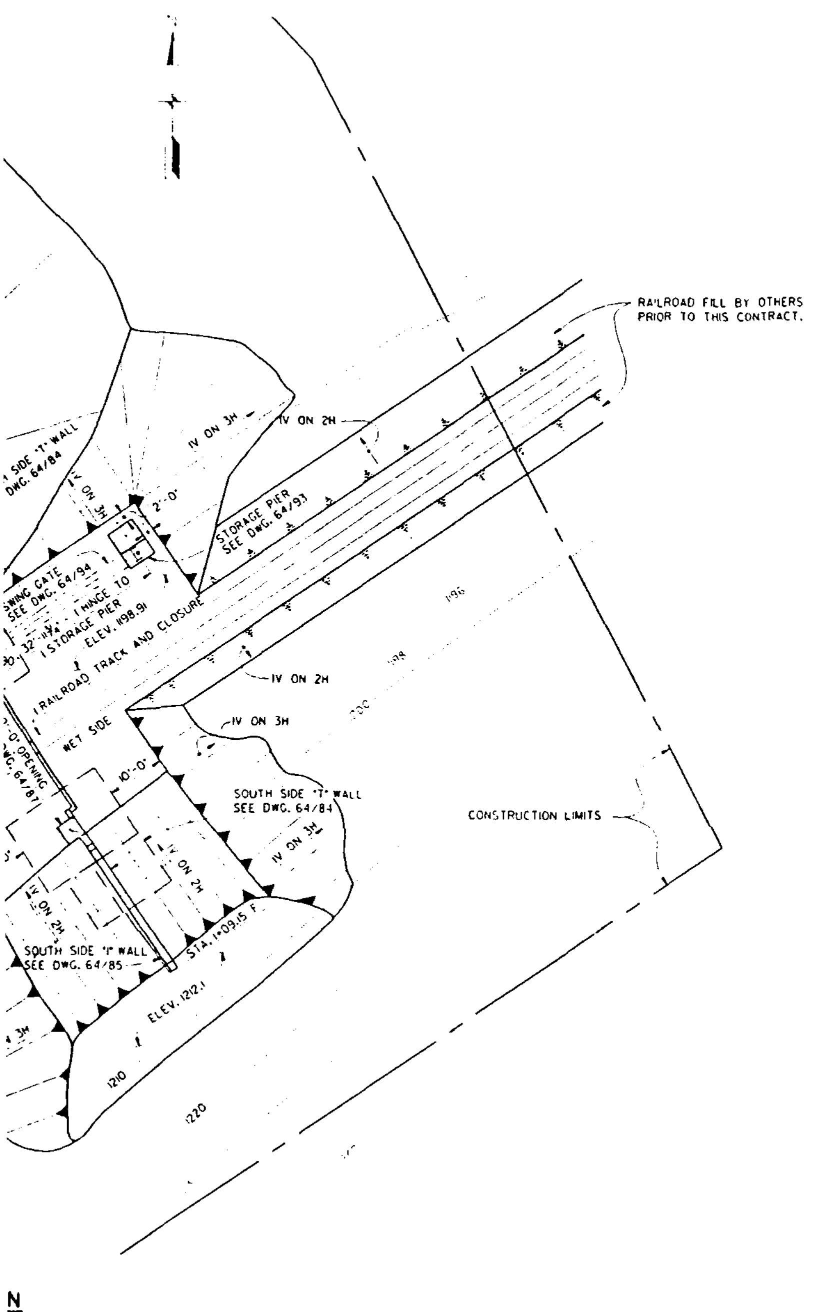
PLATE E-12

Appendix F - Floodwall and Closure Structure

Plate No.	Drawing No.	Description
F-1	Q1A-64/82	General Plan
F-2	Q1A-64/83.3	Plan and Elevation
F-3	------	Piling Records
F-4	Q1A-64/84.1	T-Wall Details
F-5	Q1A-64/91.1	Pile Layout
F-6	------	Pile Records


IV ON 3H
ELEV. 1212.1
LEVEE
1'-0"
STA. 6+91.5 E = STA. 0+00 F
IV ON 3H
STA. 6+93 E
NORTH SIDE "I" WALL SEE DWG. 64/85
NORTH SIDE "T" WALL SEE DWG. 64/84
IV ON 3H
IV ON 3H
IV ON 2H
2'-0"
STORAGE PIER SEE DWG. 64/93
SWING GATE SEE DWG. 64/94
HINGE TO STORAGE PIER ELEV. 1198.91
RAILROAD TRACK AND CLOSURE
IV ON 3H
IV ON 2H
IV ON 3H
IV ON 2.64H
WARP
WARP
10' RAMP
4' DITCH
30'-0" OPENING SEE DWG. 64/87
WET SIDE
DRY SIDE
IV ON 3H
10'-0"
10'-0"
10'-0"
IV ON 3H
SOUTH SIDE "T" WALL SEE DWG. 64/84
IV ON 3H
IV ON 2H
IV ON 2H
KDOT TYPE "A" MANHOLE
INVERT EL. 1190.4
TOP OF MANHOLE EL. 1200.9
(6" ABOVE FINISH GRADE MIN.)
STONE PROTECTION (SEE DWG. 64/45)
IV ON 2H
12"~ CMP
IV ON 3H
SOUTH SIDE "I" WALL SEE DWG. 64/85
STA. 1+09.5 F
SEE DETAIL A
GRADE TO DRAIN
EXISTING 12"~ CIP INVERT EL. 1191.85
1200
IV ON 3H
ELEV. 1212.1
1210
1220
IV ON 2H
PLAN
10'
4
12"~ CMP
PLAN
CLASS E AGGREGATE
EXISTING GROUND
OUTLET ELEV. TO BE DETERMINED IN FIELD
12"~ CMP
10
1'-6"
SECTION
DETAIL A
SCALE: 1" = 5'
NOTES:
1. FOR DETAILS OF KDOT TYPE "A" MANHOLE, SEE KDOT STANDARD DRAWINGS RDM-001-03 AND RDB-430-02.
2. EXACT LOCATION, ALIGNMENT, AND OUTLET OF 12" CPM TO BE DETERMINED IN FIELD BY CONTRACTOR.

1)



STRUCTURAL NOTES:

1. ALL CORNERS SHALL BE CHAMFERED 1" UNLESS NOTED OTHERWISE.
2. ALL STRUCTURAL SHAPES, PLATES AND BARS SHALL BE ASTM-36, UNLESS NOTED OTHERWISE.
3. ALL WELDING SHALL BE IN ACCORDANCE WITH APPLICABLE PORTION OF THE AMERICAN WELDING SOCIETY'S STRUCTURAL WELDING CODE D1.1 AND AND D1.4.
4. ALL WELDS THAT ARE TO BE GROUND SHALL HAVE A FINISHED SURFACE EQUAL TO OR SMOOTHER THAN THE MILL FINISH OF THE MATERIAL BEING WELDED UNLESS NOTED OTHERWISE.
5. ALL STEEL DENOTED CRES SHALL BE CORROSION RESISTING STEEL. SEE SPECIFICATIONS.
6. ALL WELDS ON CORROSION-RESISTING STEEL SHALL BE MADE WITH CRES ELECTRODE.
7. ALL REINFORCEMENT SHALL HAVE A MINIMUM COVER OF 4"
8. REINFORCING BAR SIZES ARE INDICATED ON THE DRAWINGS BY NUMBERS 3 THRU 11 IN CONFORMANCE WITH ASTM SPECIFICATION-615, GRADE 60. UNLESS OTHERWISE SHOWN OR DIRECTED. BAR BENDING DETAILS SHALL CONFORM TO THE REQUIREMENTS OF THE CONCRETE REINFORCING STEEL INSTITUTE.
9. BAR SPLICES SHALL BE AT LOCATIONS SHOWN ON THE DRAWING OR AS OTHERWISE APPROVED BY THE CONTRACTING OFFICER.
10. WHERE RE-BAR ARE SHOWN PASSING THROUGH SHEET PILING A HOLE SHALL BE BURNED IN THE SHEET PILING. THE HOLE SIZE SHALL NOT EXCEED 1/2" CLEAR DISTANCE AROUND THE BAR OR BARS.
11. ALL REINFORCEMENT IN THE TOP SURFACE OF THE CLOSURE STRUCTURE BETWEEN FACE TO FACE OF PIERS SHALL BE EPOXY COATED.
12. SPLICES AND ANCHORAGE FOR REINFORCEMENT BARS SHALL BE IN ACCORDANCE WITH "BUILDING CODE REQUIREMENTS FOR REINFORCED CONCRETE (ACI 318-83)". MINIMUM SPLICES AND EMBEDMENT LENGTHS ARE SHOWN IN THE TABLE ON DWG. 64/87. EXCEPT AS SHOWN OR NOTED ON THE DRAWINGS.
13. ALL CONCRETE SHALL HAVE A MINIMUM COMPRESSIVE STRENGTH (f'c) OF 3000 P.S.I. AT 28 DAYS UNLESS NOTED OTHERWISE.
14. FOR GENERAL NOTES, SEE DRAWING 64/2.
15. ALL EXPOSED CONCRETE SURFACES SHALL RECEIVE A SACK-RUBBED FINISH.

REVISION	DATE	DESCRIPTION	BY	CHKD.

GRAPHIC SCALE

DEPARTMENT OF THE ARMY
NASHVILLE DISTRICT, CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

DRAWN: D. J.
CHECKED: D. J. & M. W.
TRACED:
COMPARED:
W. M. WILSON
ENGINEER

UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY

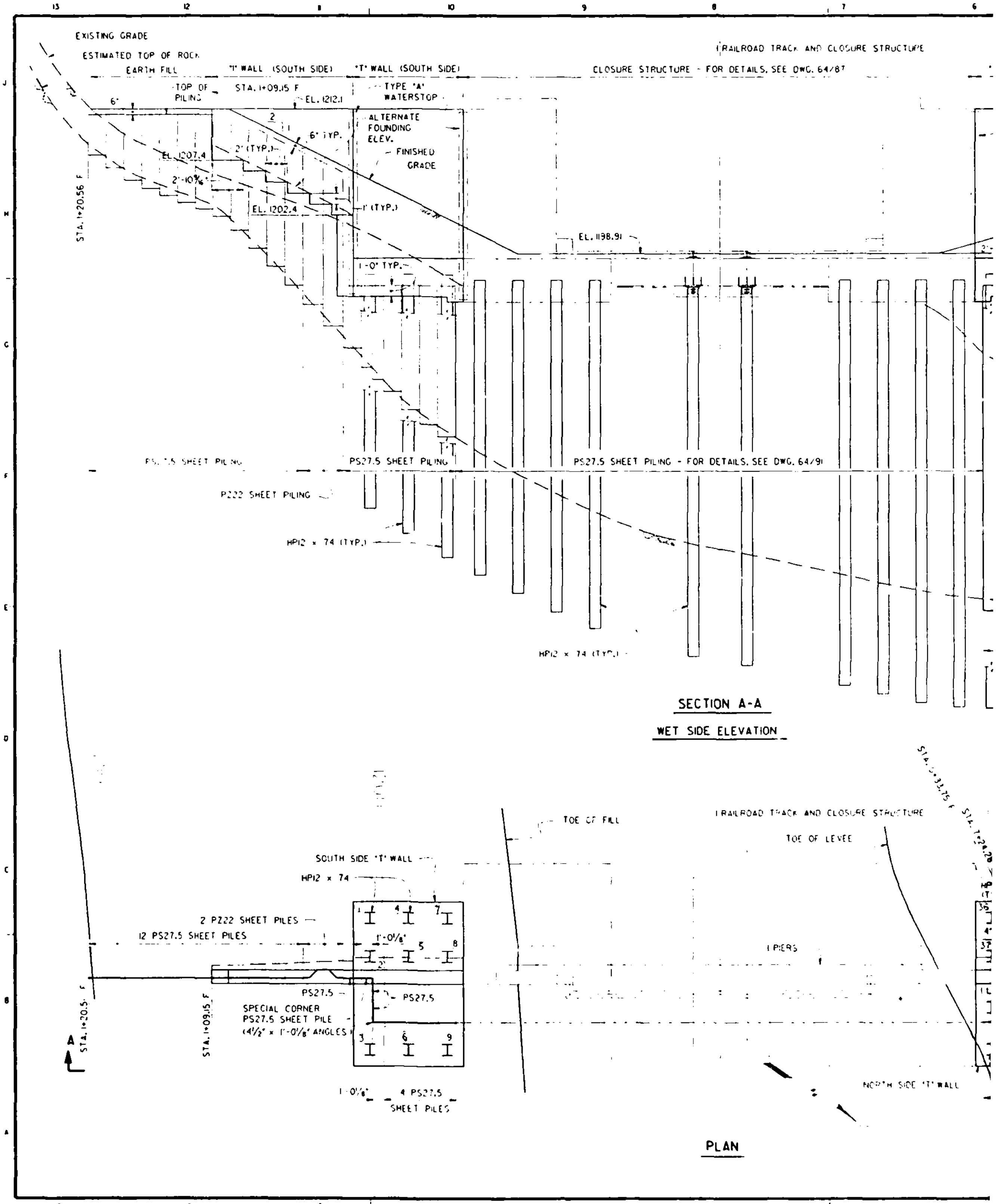
FLOODWALL & CLOSURE STRUCTURE
GENERAL PLAN

SUBMITTED:
CHIEF, DESIGN BRANCH
APPROVAL RECOMMENDED:
CHIEF, ENGINEERING DIVISION
APPROVED:
COLONEL, C.E. DISTRICT ENGINEER
DATE: MARCH 1989
SCALE: 1"=10'-0"
SPEC. NO.
DRAWING NUMBER
SHEET OF
01A-64/82

RECORD DRAWING AS CONSTRUCTED DATED

Computer Aided Design & Drafting

PLATE F-1


EXISTING GRADE
ESTIMATED TOP OF ROCK
EARTH FILL
"T" WALL (SOUTH SIDE)
"T" WALL (SOUTH SIDE)
RAILROAD TRACK AND CLOSURE STRUCTURE
CLOSURE STRUCTURE - FOR DETAILS, SEE DWG. 64/87
TOP OF PILING
STA. 1+09.15 F
EL. 1212.1
TYPE "A" WATERSTOP
ALTERNATE FOUNDING ELEV.
FINISHED GRADE
6" TYP.
2' (TYP.)
EL. 1207.4
2'-10⅝"
EL. 1202.4
1' (TYP.)
STA. 1+20.56 F
EL. 1198.91
1'-0" TYP.
PS27.5 SHEET PILING
PS27.5 SHEET PILING - FOR DETAILS, SEE DWG. 64/91
PZ22 SHEET PILING
HP12 x 74 (TYP.)
HP12 x 74 (TYP.)
SECTION A-A
WET SIDE ELEVATION
TOE OF FILL
RAILROAD TRACK AND CLOSURE STRUCTURE
TOE OF LEVEE
SOUTH SIDE "T" WALL
HP12 x 74
2 PZ22 SHEET PILES
12 PS27.5 SHEET PILES
1'-0⅛"
PIERS
PS27.5
PS27.5
SPECIAL CORNER PS27.5 SHEET PILE (4½" x 1'-0⅛" ANGLES)
STA. 1+20.5 F
STA. 1+09.15 F
1'-0⅛"
4 PS27.5 SHEET PILES
NORTH SIDE "T" WALL
PLAN

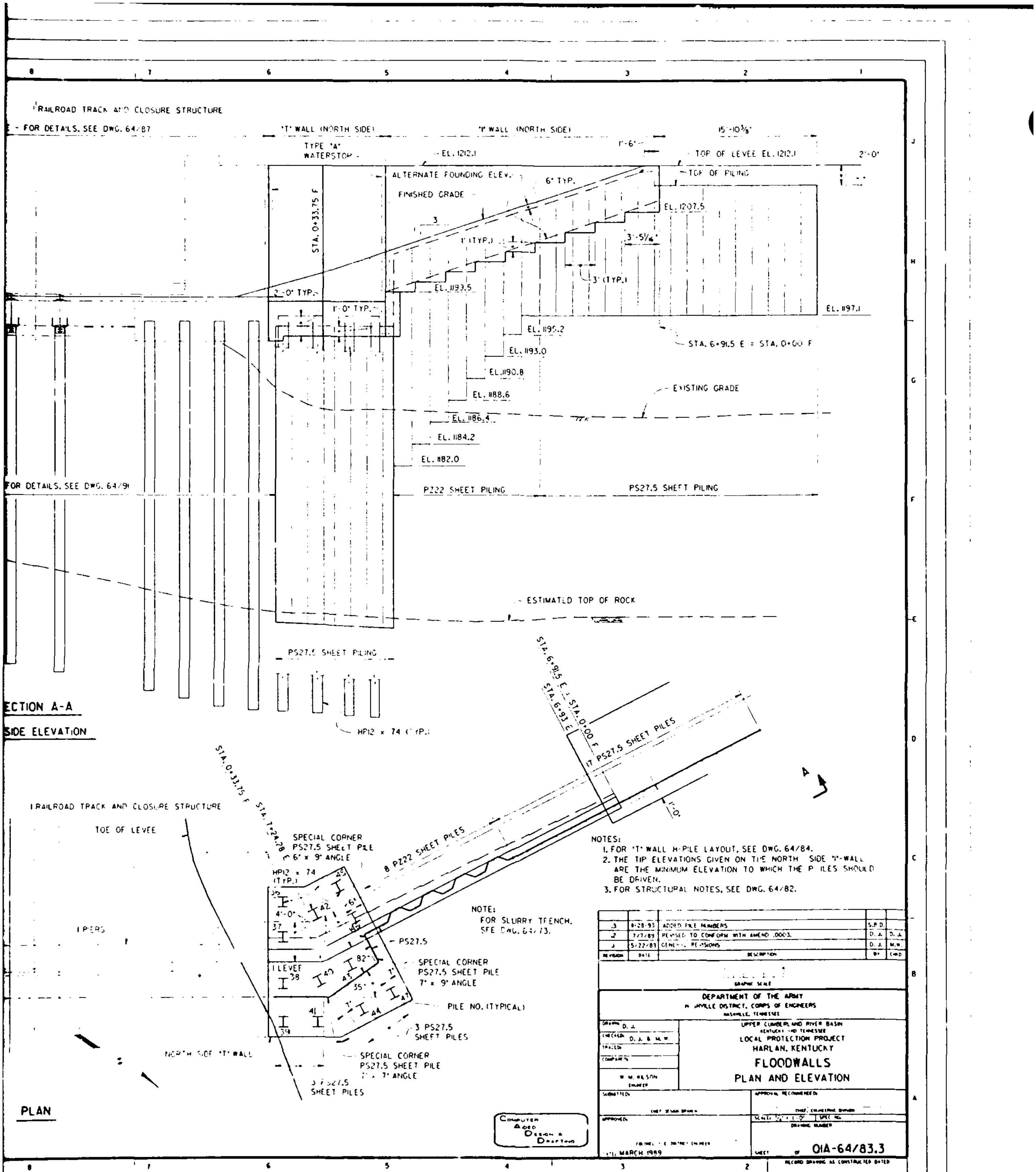
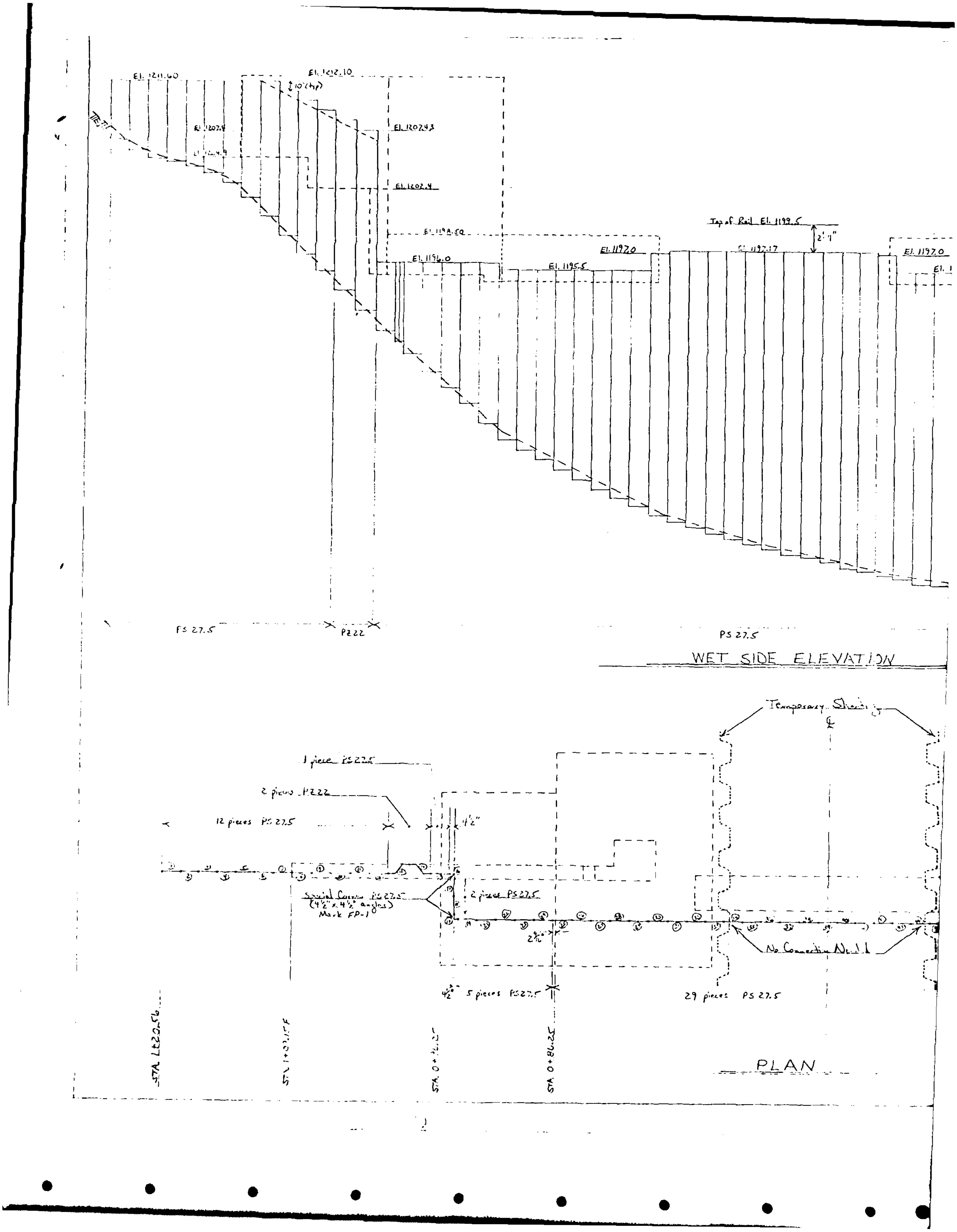

RAILROAD TRACK AND CLOSURE STRUCTURE
FOR DETAILS, SEE DWG. 64/87
'T' WALL (NORTH SIDE)
'T' WALL (NORTH SIDE)
TYPE 'A' WATERSTOP
EL. 1212.1
TOP OF LEVEE EL. 1212.1
TOP OF PILING
ALTERNATE FOUNDING ELEV.
6" TYP.
FINISHED GRADE
STA. 0+33.75 F
EL. 1207.5
1' (TYP.)
3'-5 1/16"
3' (TYP.)
EL. 1193.5
2'-0" TYP.
1'-0" TYP.
EL. 1197.1
EL. 1195.2
EL. 1193.0
EL. 1190.8
EL. 1188.6
EL. 1186.4
EL. 1184.2
EL. 1182.0
STA. 6+91.5 E = STA. 0+00 F
EXISTING GRADE
FOR DETAILS, SEE DWG. 64/91
PZ22 SHEET PILING
PS27.5 SHEET PILING
ESTIMATED TOP OF ROCK
PS27.5 SHEET PILING
HP12 x 74 (TYP.)
SECTION A-A
SIDE ELEVATION
STA. 6+91.5 E = STA. 0+00 F
STA. 6+93 E
17 PS27.5 SHEET PILES
1'-0"
STA. 0+33.75 F
STA. 1+24.28
RAILROAD TRACK AND CLOSURE STRUCTURE
TOE OF LEVEE
SPECIAL CORNER PS27.5 SHEET PILE 6" x 9" ANGLE
HP12 x 74 (TYP.)
8 PZ22 SHEET PILES
NOTE:
FOR SLURRY TRENCH, SEE DWG. 64/73.
PIERS
PS27.5
SPECIAL CORNER PS27.5 SHEET PILE 7" x 9" ANGLE
LEVEE
PILE NO. (TYPICAL)
3 PS27.5 SHEET PILES
NORTH SIDE 'T' WALL
SPECIAL CORNER PS27.5 SHEET PILE 7" x 7" ANGLE
3 PS27.5 SHEET PILES
PLAN
NOTES:
1. FOR 'T' WALL H-PILE LAYOUT, SEE DWG. 64/84.
2. THE TIP ELEVATIONS GIVEN ON THE NORTH SIDE 'T'-WALL ARE THE MINIMUM ELEVATION TO WHICH THE PILES SHOULD BE DRIVEN.
3. FOR STRUCTURAL NOTES, SEE DWG. 64/82.
3 8-28-93 ADDED PILE NUMBERS
2 7/7/89 REVISED TO CONFORM WITH AMEND 0003
1 5/22/89 GENERAL REVISIONS
REVISION DATE DESCRIPTION BY CHKD
DEPARTMENT OF THE ARMY
NASHVILLE DISTRICT, CORPS OF ENGINEERS
NASHVILLE, TENNESSEE
UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
FLOODWALLS
PLAN AND ELEVATION
COMPUTER AIDED DESIGN & DRAFTING
MARCH 1989
OIA-64/83.3
RECORD DRAWING AS CONSTRUCTED DATED

PLATE F-2


El. 1211.60
El. 1212.10
El. 1207.4
El. 1202.43
El. 1202.4
El. 1198.50
El. 1196.0
El. 1195.5
El. 1197.0
Top of Rail El. 1199.5
El. 1197.17
El. 1197.0
PS 27.5
PZ22
PS 27.5
WET SIDE ELEVATION
Temporary Sheeting
1 piece PS27.5
2 pieces PZ22
12 pieces PS 27.5
4'2"
Special Corner PS27.5
(4½" x 4½" angles)
Mark FP-1
2 pieces PS27.5
4½" 5 pieces PS27.5
29 pieces PS 27.5
No Connection Needed
STA. 0+86.25
PLAN

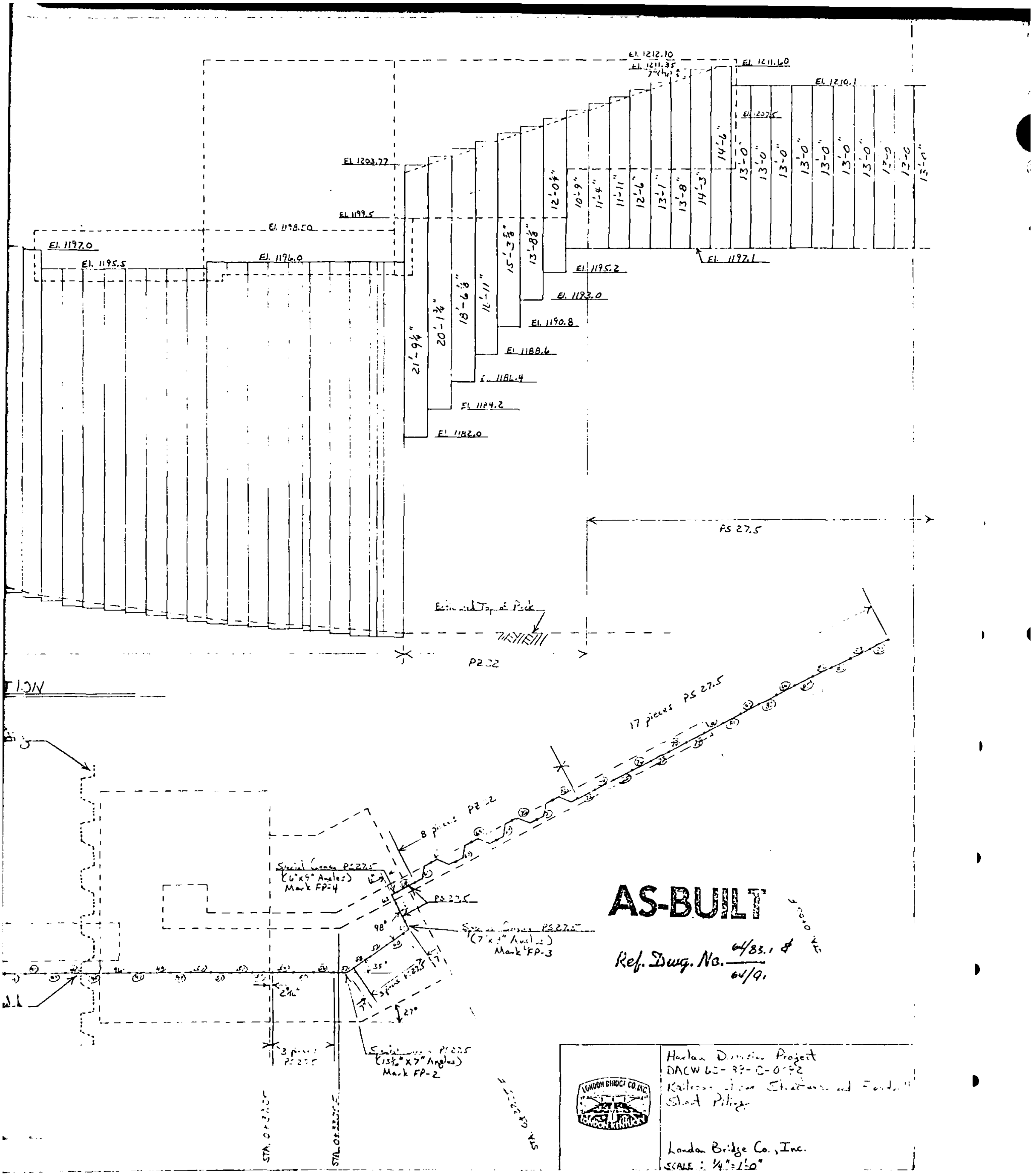
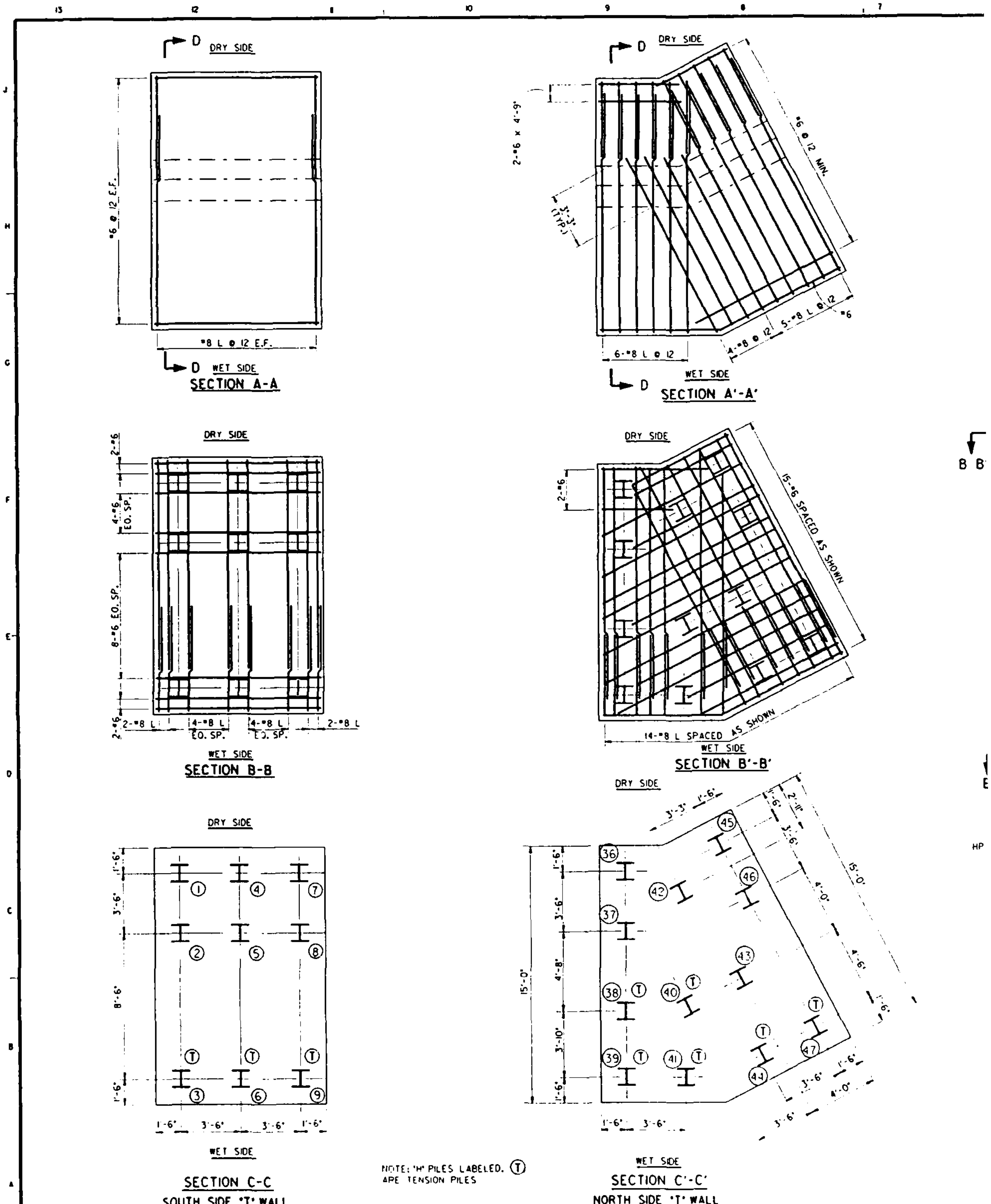
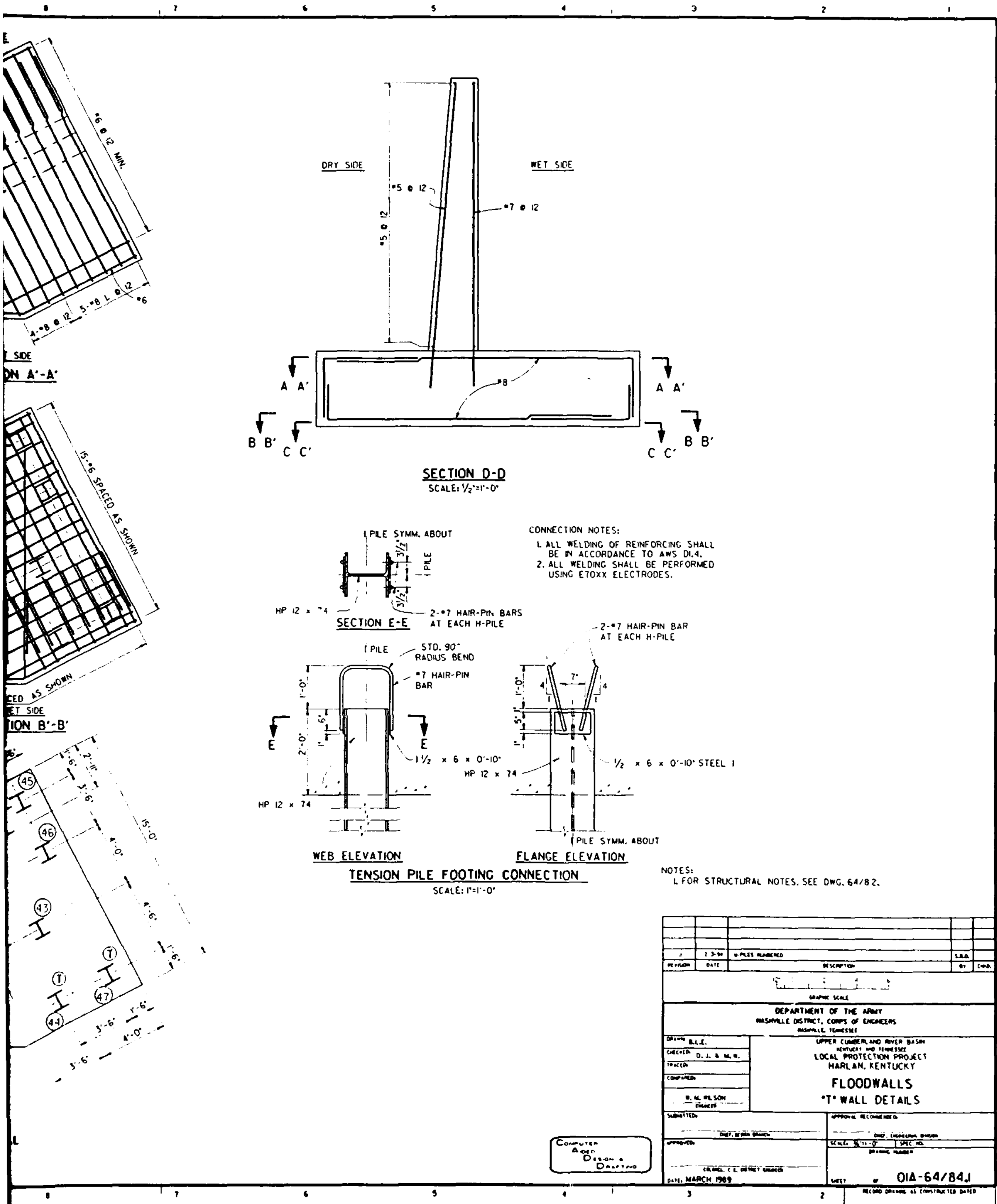

El. 1212.10
El. 1211.35
El. 1211.60
El. 1210.1
El. 1207.5
El. 1203.77
El. 1199.5
El. 1198.50
El. 1197.0
El. 1195.5
El. 1196.0
El. 1197.1
El. 1195.2
El. 1193.0
El. 1190.8
El. 1188.6
El. 1186.4
El. 1184.2
El. 1182.0
21'-9¾"
20'-1¾"
18'-6⅜"
16'-11"
15'-3⅝"
13'-8⅞"
12'-0¾"
10'-9"
11'-4"
11'-11"
12'-6"
13'-1"
13'-8"
14'-3"
14'-6"
13'-0"
PS 27.5
PZ 22
17 pieces PS 27.5
8 pieces PZ 22
Special Corner PS27.5
(6"x5" Angles)
Mark FP-4
Special Corner PS27.5
(7"x5" Angles)
Mark FP-3
Special Corner PS27.5
(13⅛"x7" Angles)
Mark FP-2
3 pieces PS27.5
98°
35°
27°
AS-BUILT
Ref. Dwg. No. 64/83.1 & 64/91
Harlan Diversion Project
DACW 62-79-C-0092
London Bridge Co., Inc.
SCALE: ¼"=1'-0"

PLATE F-3

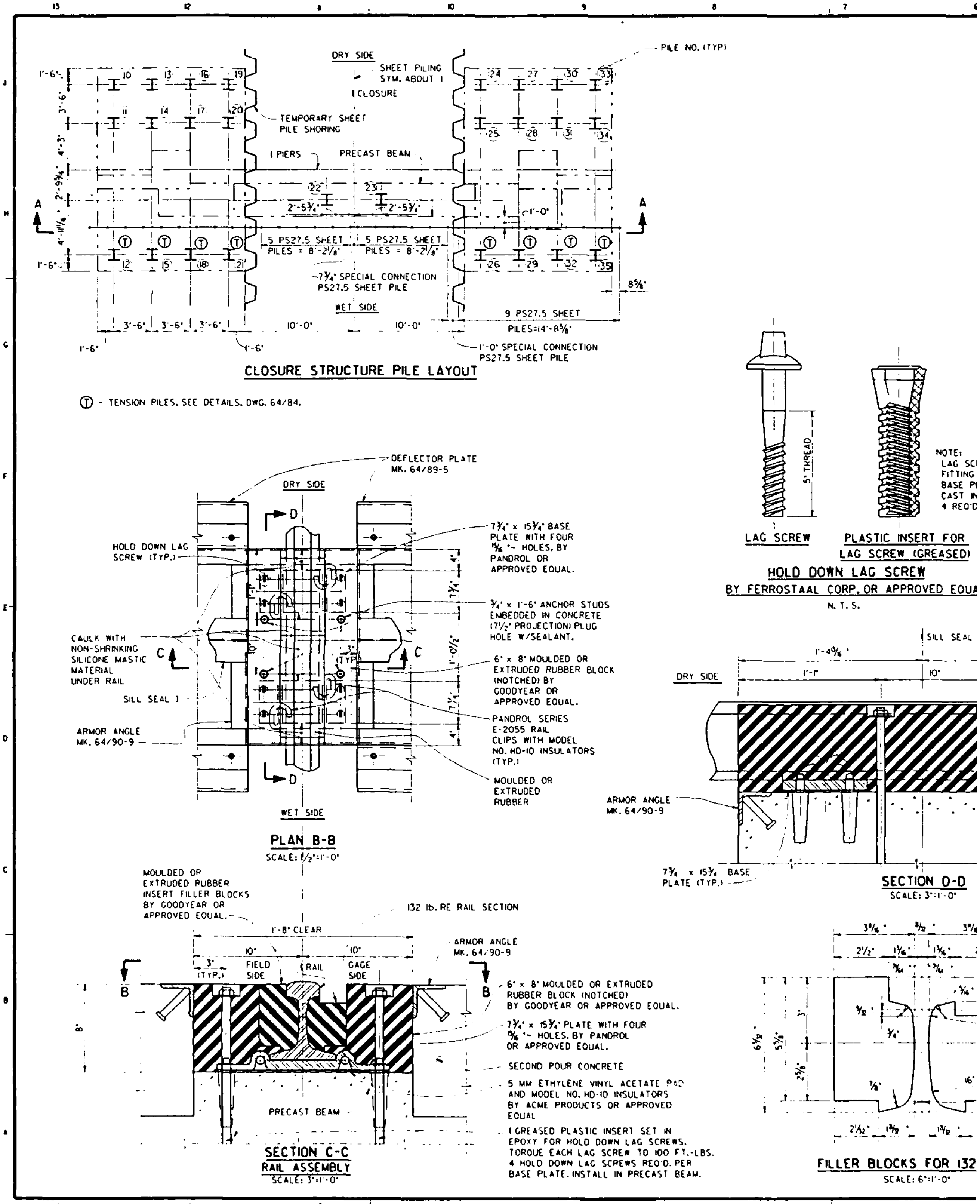


'T' WALL PILING & REINFORCEMENT

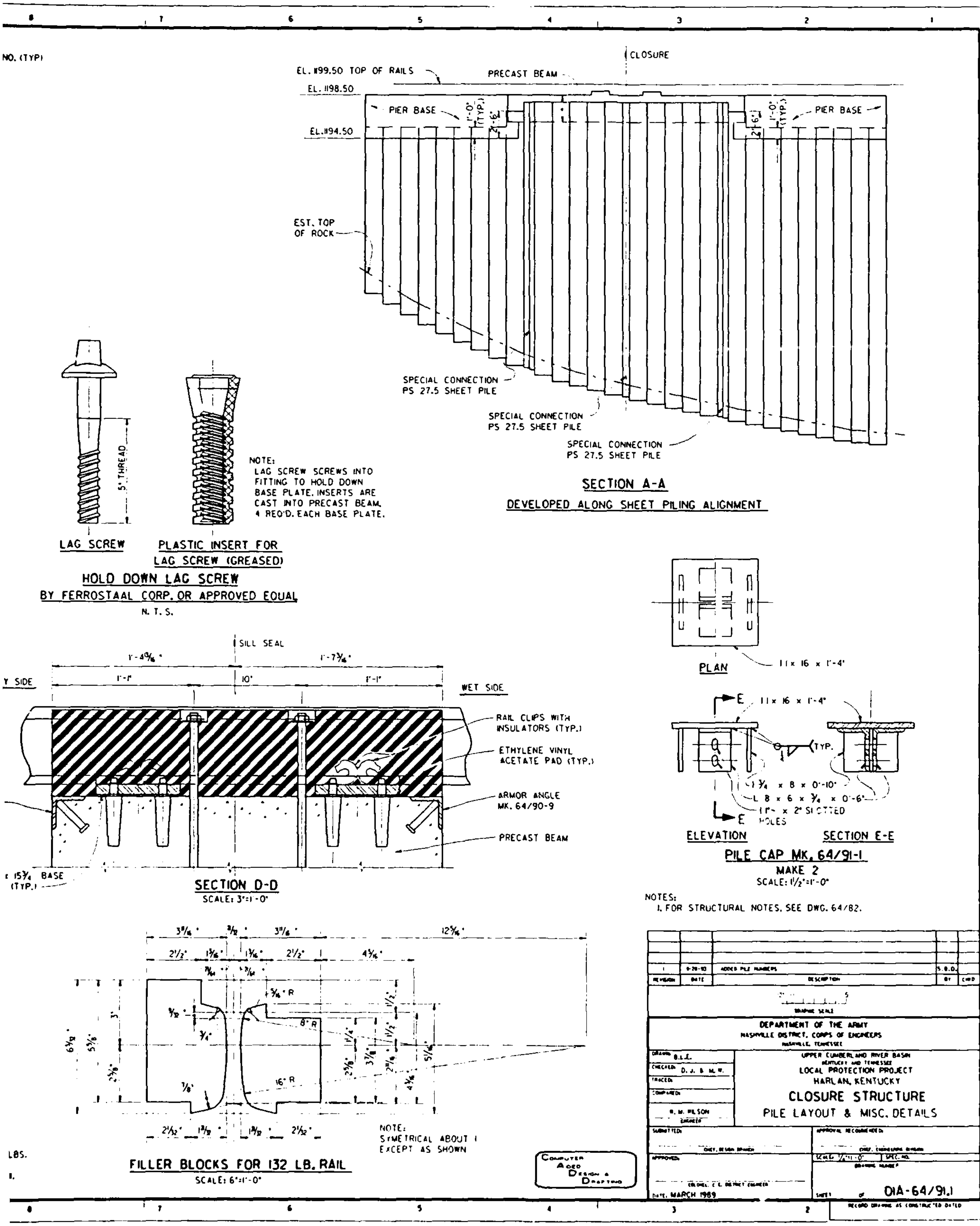


DRY SIDE
WET SIDE
#5 @ 12
#7 @ 12
#8
A A'
B B'
C C'
SECTION D-D
SCALE: 1/2"=1'-0"
CONNECTION NOTES:
1. ALL WELDING OF REINFORCING SHALL BE IN ACCORDANCE TO AWS D1.4.
2. ALL WELDING SHALL BE PERFORMED USING E70XX ELECTRODES.
PILE SYMM. ABOUT
HP 12 x 74
2-#7 HAIR-PIN BARS AT EACH H-PILE
SECTION E-E
2-#7 HAIR-PIN BAR AT EACH H-PILE
STD. 90° RADIUS BEND
#7 HAIR-PIN BAR
1 1/2 x 6 x 0'-10"
1/2 x 6 x 0'-10" STEEL
WEB ELEVATION
FLANGE ELEVATION
TENSION PILE FOOTING CONNECTION
SCALE: 1"=1'-0"
NOTES:
1. FOR STRUCTURAL NOTES. SEE DWG. 64/82.
15-#6 SPACED AS SHOWN
#6 @ 12 MIN.
SECTION A'-A'
SECTION B'-B'
DEPARTMENT OF THE ARMY
NASHVILLE DISTRICT, CORPS OF ENGINEERS
NASHVILLE, TENNESSEE
UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
FLOODWALLS
"T" WALL DETAILS
DATE: MARCH 1989
01A-64/84.1
COMPUTER AIDED DESIGN & DRAFTING

PLATE F-4



DRY SIDE
SHEET PILING SYM. ABOUT ℄
℄ CLOSURE
PILE NO. (TYP)
TEMPORARY SHEET PILE SHORING
℄ PIERS
PRECAST BEAM
2'-5¾"
2'-5¾"
1'-0"
5 PS27.5 SHEET PILES = 8'-2⅛"
5 PS27.5 SHEET PILES = 8'-2⅛"
7¾" SPECIAL CONNECTION PS27.5 SHEET PILE
WET SIDE
9 PS27.5 SHEET PILES=14'-8⅝"
8⅝"
3'-6"
3'-6"
3'-6"
10'-0"
10'-0"
1'-6"
1'-0" SPECIAL CONNECTION PS27.5 SHEET PILE
CLOSURE STRUCTURE PILE LAYOUT
Ⓣ - TENSION PILES. SEE DETAILS, DWG. 64/84.
DEFLECTOR PLATE MK. 64/89-5
DRY SIDE
HOLD DOWN LAG SCREW (TYP.)
7¾" x 15¾" BASE PLATE WITH FOUR 1⁵⁄₁₆"⌀ HOLES, BY PANDROL OR APPROVED EQUAL.
¾" x 1'-6" ANCHOR STUDS EMBEDDED IN CONCRETE (7½" PROJECTION) PLUG HOLE W/SEALANT.
CAULK WITH NON-SHRINKING SILICONE MASTIC MATERIAL UNDER RAIL
6" x 8" MOULDED OR EXTRUDED RUBBER BLOCK (NOTCHED) BY GOODYEAR OR APPROVED EQUAL.
SILL SEAL
ARMOR ANGLE MK. 64/90-9
PANDROL SERIES E-2055 RAIL CLIPS WITH MODEL NO. HD-10 INSULATORS (TYP.)
MOULDED OR EXTRUDED RUBBER
WET SIDE
PLAN B-B
SCALE: 1½"=1'-0"
LAG SCREW
5" THREAD
PLASTIC INSERT FOR LAG SCREW (GREASED)
HOLD DOWN LAG SCREW
BY FERROSTAAL CORP. OR APPROVED EQUA
N. T. S.
NOTE:
LAG SC
FITTING
BASE P
CAST IN
4 REQ'D
SILL SEAL
1'-4⁹⁄₁₆"
1'-1"
10"
DRY SIDE
ARMOR ANGLE MK. 64/90-9
7¾" x 15¾" BASE PLATE (TYP.)
SECTION D-D
SCALE: 3"=1'-0"
MOULDED OR EXTRUDED RUBBER INSERT FILLER BLOCKS BY GOODYEAR OR APPROVED EQUAL.
132 lb. RE RAIL SECTION
1'-8" CLEAR
ARMOR ANGLE MK. 64/90-9
10"
10"
3" (TYP.)
FIELD SIDE
℄ RAIL
GAGE SIDE
6" x 8" MOULDED OR EXTRUDED RUBBER BLOCK (NOTCHED) BY GOODYEAR OR APPROVED EQUAL.
7¾" x 15¾" PLATE WITH FOUR ⁹⁄₁₆"⌀ HOLES. BY PANDROL OR APPROVED EQUAL.
SECOND POUR CONCRETE
5 MM ETHYLENE VINYL ACETATE PAD AND MODEL NO. HD-10 INSULATORS BY ACME PRODUCTS OR APPROVED EQUAL
PRECAST BEAM
GREASED PLASTIC INSERT SET IN EPOXY FOR HOLD DOWN LAG SCREWS. TORQUE EACH LAG SCREW TO 100 FT.-LBS. 4 HOLD DOWN LAG SCREWS REQ'D. PER BASE PLATE. INSTALL IN PRECAST BEAM.
SECTION C-C
RAIL ASSEMBLY
SCALE: 3"=1'-0"
FILLER BLOCKS FOR 132
SCALE: 6"=1'-0"



NOTES:
1. FOR STRUCTURAL NOTES, SEE DWG. 64/82.

DEPARTMENT OF THE ARMY
NASHVILLE DISTRICT, CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY

CLOSURE STRUCTURE
PILE LAYOUT & MISC. DETAILS

DATE: MARCH 1989

DIA-64/91.1

PLATE F-5

RAILROAD CLOSURE STRUCTURE AND FLOODWALLS
H-PILE RECORD DATA

PILE NO.	TYPE	CUT-OFF ELEV.	TIP ELEV.	LENGTH
1	HP12 x 74	1196.50	1175.4[illegible]	[illegible]
2		1196.50	1176.17	20.33
3		1196.50	1177.40	19.10
4		1196.50	1175.19	21.31
5		1196.50	1175.11	21.39
6		1196.50	1175.16	21.34
7		1196.50	1172.00	24.50
8		1196.50	1172.46	24.04
9		1196.50	1173.11	23.39
10		1196.50	1171.67	24.83
11		1196.50	1172.08	24.42
12		1196.50	1171.71	24.79
13		1196.19	1171.90	25.29
14		1196.24	1170.99	25.25
15		1196.25	1171.26	25.19
16		1196.50	1170.04	26.46
17		1196.50	1169.96	26.54
18		1196.50	1170.67	25.83
19		1196.50	1169.08	27.42
20		1196.50	1169.16	27.34
21		1196.50	1169.65	26.85
22		1196.00	1168.38	27.62
23		1196.00	1168.25	27.75
24		1196.50	1168.15	28.35
25		1196.50	1167.87	26.63
26		1196.50	1167.88	28.62
27		1196.50	1168.16	28.34
28		1196.50	1168.19	28.31
29		1196.50	1168.16	28.34
30		1196.50	1167.42	29.25
31		1196.50	1167.92	28.58
32		1196.50	1167.75	28.75
33		1196.50	1167.00	29.50
34		1196.50	1166.58	29.92
35		1196.50	1167.56	28.94
36		1196.50	1166.23	30.27
37		1196.50	1166.27	30.23
38		1196.50	1166.31	30.19
39		1196.50	1166.93	29.57
40		1196.50	1166.04	30.46
41		1196.50	1165.68	30.82
42		1196.50	1166.51	29.99
43		1196.50	1166.92	29.58
44		1196.50	1166.50	30.00
45		1196.50	1167.83	28.67
46		1196.50	1167.71	28.79
47	HP12 x 74	1196.50	1167.31	29.19

RAIL[illegible]

SH[illegible]

PILE NO.	TYPE	CUT-OFF ELEV.	TIP ELEV.
1	PS27[illegible]		
2		[illegible]	1207.64
3		1211.60	1206.35
4		1211.60	1202.81
5		1211.60	1201.20
6		1211.60	1200.23
7		1211.60	1196.24
8		1211.60	1197.20
9		1211.60	1194.69
10		1210.75	1190.92
11		[illegible]	[illegible]
12	PS27.5	[illegible]	[illegible]
13	PS[illegible]	[illegible]	[illegible]5.75
14	PS[illegible]	1207.47	[illegible]
15	PS27.5	1196.00	[illegible]
16	PS27.5 CORNER	1196.00	[illegible]
17	PS27.5	1196.00	1176.28
18	PS27.5	1196.00	1176.08
19	PS27.5 CORNER	1196.00	1175.75
20	PS27.5	1196.00	1177.83
21		1196.00	1176.79
22		1196.00	1175.92
23		1196.00	1174.75
24		1196.00	1173.79
25		1195.50	1173.29
26		1195.50	1172.29
27		1195.50	1172.29
28		1195.50	1171.79
29		1195.50	1171.75
30		1195.50	1171.50
31		1195.50	1171.00
32		1195.50	1170.56
33		1197.00	1169.56
34		1197.17	1170.25
35		1197.17	1169.65
36		1197.17	1169.51
37		1197.17	1169.38
38		1197.17	1169.29
39		1197.17	1169.30
40		1197.17	1169.28
41		1197.17	1169.94
42		1197.17	1169.93
43		1197.17	1170.09
44		1197.17	1166.92
45	PS27.5	1197.00	1166.79

RAILROAD CLOSURE STRUCTURE AND FLOODWALLS SHEET PILE RECORD DATA

PILE NO.	TYPE	CUT OFF EL.	TIP EL.	LENGTH		PILE NO.	TYPE	CUT OFF EL.	TIP EL.	LENGTH
1	PS27.5					46	PS27.5	1195.50	[illegible]	[illegible]
2		1211.60	1207.64	3.96		47		1195.50	[illegible]	26.75
3		1211.60	1206.35	5.25		48		1195.50	1168.58	26.92
4		1211.60	1202.81	8.79		49		1195.50	1168.50	27.00
5		1211.60	1201.20	10.40		50		1195.50	1168.83	26.67
6		1211.60	1200.23	11.37		51		1195.50	1168.58	26.92
7		1211.60	1198.04	13.56		52		1195.50	1168.50	27.00
8		1211.60	1197.00	14.60		53		1195.50	1168.42	27.08
9		1211.60	1194.89	16.71		54		1196.00	1168.83	27.17
10		1210.75	1192.92	17.83		55		1196.00	1167.83	28.17
11		1209.90	1189.80	20.10		56	PS27.5	1196.00	1166.83	29.17
12	PS27.5	1209.09	1187.82	21.27		57	PS27.5 CORNER	1196.00	1167.08	28.92
13	PZ22	1208.25	1185.79	22.46		58	PS27.5	1196.00	1167.33	28.67
14	PZ22	1207.43	1183.00	24.43		59	PS27.5	1196.00	1167.50	28.50
15	PS27.5	1196.00	1179.03	16.97		60	PS27.5	1196.00	1167.75	28.25
16	PS27.5 CORNER	1196.00	1178.17	17.83		61	PS27.5 CORNER	1196.00	1169.00	27.00
17	PS27.5	1196.00	1178.08	17.92		62	PS27.5	1196.00	1168.25	27.75
18	PS27.5	1196.00	1178.08	17.92		63	PS27.5 CORNER	1196.00	1168.35	27.65
19	PS27.5 CORNER	1196.00	1178.75	17.25		64	PS27.5	1196.00	1168.29	27.71
20	PS27.5	1196.00	1177.83	18.17		65	PZ22	1203.77	1182.00	21.77
21		1196.00	1176.79	19.21		66		1204.25	1184.20	20.05
22		1196.00	1175.92	20.08		67		1204.93	1188.40	16.53
23		1196.00	1174.75	21.25		68		1205.52	1188.60	16.92
24		1196.00	1173.79	22.21		69		1206.10	1190.80	15.30
25		1195.50	1173.29	22.21		70		1206.66	1193.00	13.66
26		1195.50	1172.29	23.21		71		1207.26	1195.20	12.06
27		1195.50	1172.29	23.33		72	PZ22	1207.85	1197.10	10.75
28		1195.50	1171.79	23.71		73	PS27.5	1208.43	1197.10	11.33
29		1195.50	1171.75	23.75		74		1209.02	1197.10	11.92
30		1195.50	1171.50	24.00		75		1209.60	1197.10	12.50
31		1195.50	1171.00	24.50		76		1210.18	1197.10	13.08
32		1195.50	1170.56	24.94		77		1210.77	1197.10	13.67
33		1197.00	1169.54	27.46		78		1211.35	1197.10	14.25
34		1197.17	1170.25	26.92		79		1211.60	1197.10	14.50
35		1197.17	1169.65	27.52		80		1210.10	1197.10	13.00
36		1197.17	1169.51	27.66		81		1210.10	1197.10	13.00
37		1197.17	1169.30	27.87		82		1210.10	1197.10	13.00
38		1197.17	1169.29	27.88		83		1210.10	1197.10	13.00
39		1197.17	1169.30	27.87		84		1210.10	1197.10	13.00
40		1197.17	1169.28	27.89		85		1210.10	1197.10	13.00
41		1197.17	1169.94	27.23		86		1210.10	1197.10	13.00
42		1197.17	1169.93	27.24		87		1210.10	1197.10	13.00
43		1197.17	1170.09	27.08		88		1210.10	1197.10	13.00
44		1197.17	1168.92	28.25		89	PS27.5	1210.10	1197.10	13.00
45	PS27.5	1197.00	1168.79	28.21						

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

Drawn By: JTM
Checked By:
Approved By:

HARLAN DIVERSION PROJECT
AS CONSTRUCTED
RAILROAD CLOSURE STRUCTURE and FLOODWALLS
H-PILE and SHEET PILE RECORDS

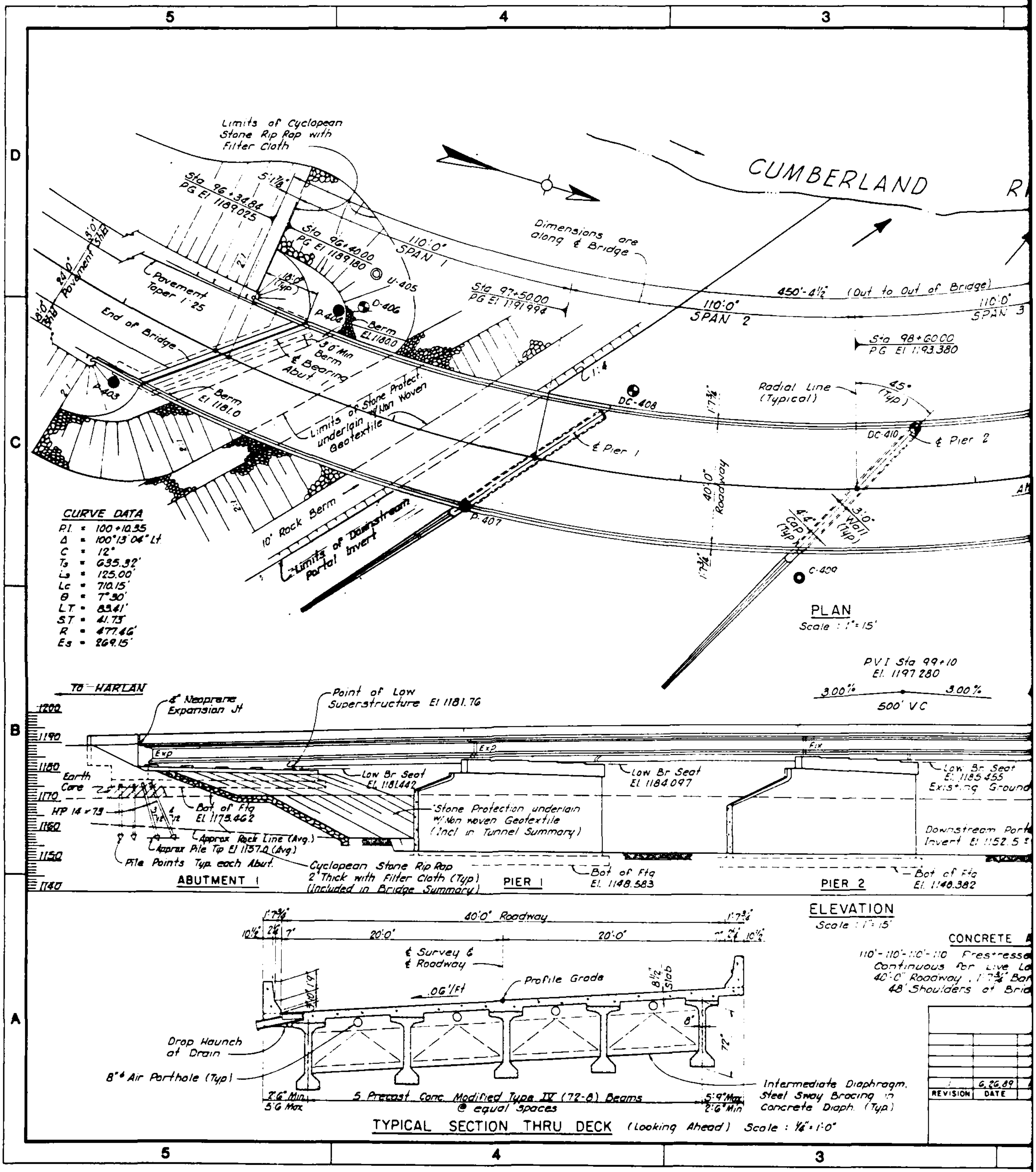
Date: JAN 1994

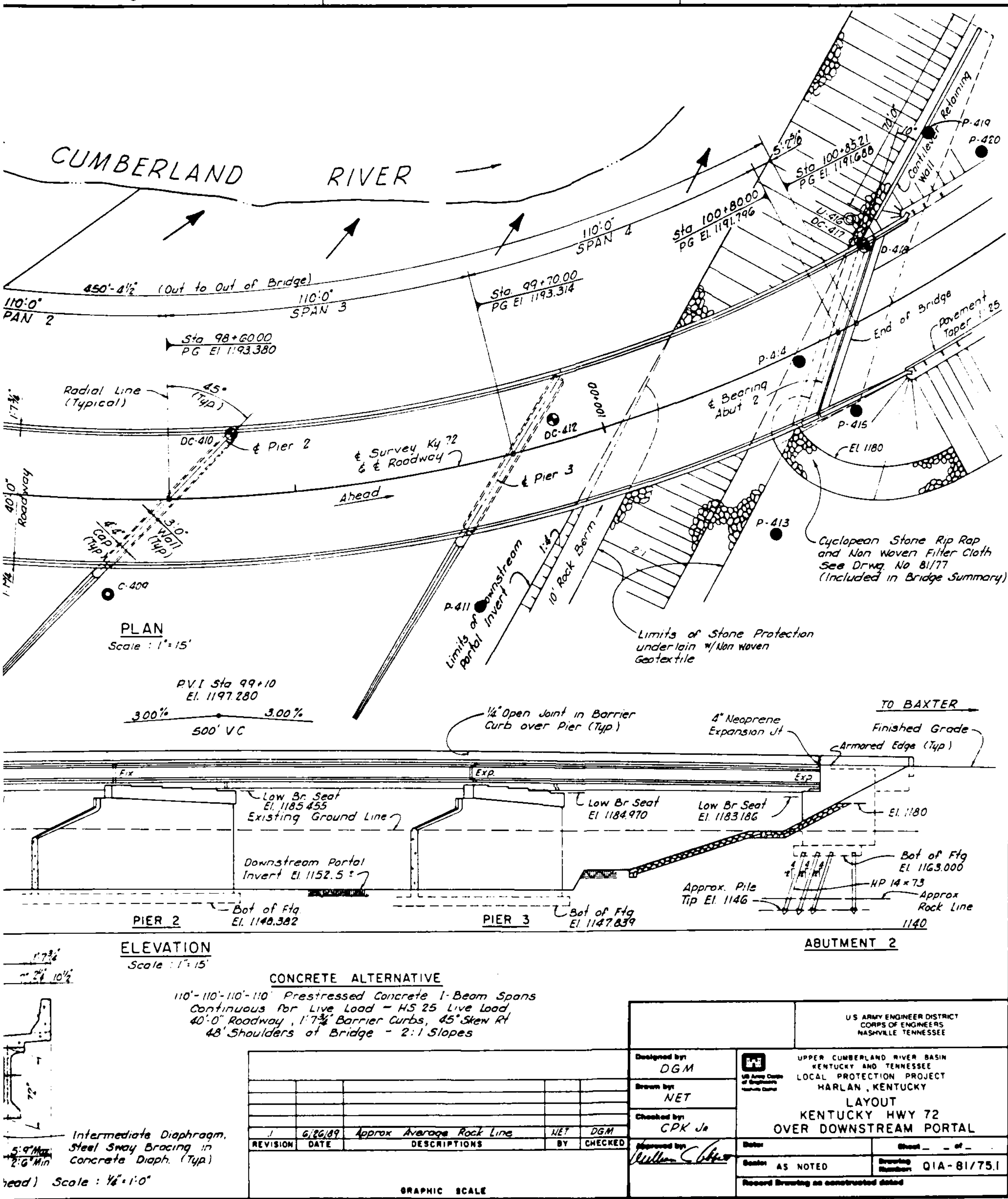
Record Drawing as constructed dated

PLATE F-6

Appendix G - Highway 72 Bridge

Plate No.	Drawing No.	Description
G-1	Q1A-81/75.1	Bridge Layout
G-2	Q1A-81/76.2	Pile Layout & Record
G-3	Q1A-81/79.1	Pier Details
G-4	Q1A-4/398	Pier Foundation Maps


CUMBERLAND R
Limits of Cyclopean Stone Rip Rap with Filter Cloth
Sta 96+34.84 PG El 1189.025
Sta 96+40.00 PG El 1189.180
Dimensions are along ℄ Bridge
110'-0" SPAN 1
110'-0" SPAN 2
110'-0" SPAN 3
450'-4½" (Out to Out of Bridge)
Sta 97+50.00 PG El 1191.994
Sta 98+60.00 PG El 1193.380
Pavement Taper 1:25
End of Bridge
24'-0" Pavement
Berm El 1180.0
Berm El 1181.0
3'-0" Min Berm
℄ Bearing Abut 1
Limits of Stone Protect. underlain w/ Non Woven Geotextile
10' Rock Berm
Limits of Downstream Portal Invert
℄ Pier 1
℄ Pier 2
Radial Line (Typical)
45° (Typ)
40'-0" Roadway
Cap (Typ)
Wall (Typ)
CURVE DATA
P.I. = 100+10.35
Δ = 100°13'04" Lt
C = 12°
Ts = 635.32'
Ls = 125.00'
Lc = 710.15'
θ = 7°30'
LT = 83.41'
ST = 41.73'
R = 477.46'
Es = 269.15'
PLAN
Scale : 1" = 15'
TO HARLAN
4" Neoprene Expansion Jt
Point of Low Superstructure El 1181.76
PVI Sta 99+10 El 1197.280
3.00%
3.00%
500' VC
Exp
Fix
Low Br Seat El 1181.442
Low Br Seat El 1184.097
Low Br Seat El 1185.455
Existing Ground
Earth Core
HP 14 × 73
Bot of Ftg El 1175.462
Approx Rock Line (Avg.)
Approx Pile Tip El 1157.0 (Avg)
Pile Points Typ. each Abut.
Stone Protection underlain w/ Non woven Geotextile (Incl in Tunnel Summary)
Cyclopean Stone Rip Rap 2' Thick with Filter Cloth (Typ) (Included in Bridge Summary)
Downstream Portal Invert El 1152.5
Bot of Ftg El 1148.583
Bot of Ftg El 1148.382
ABUTMENT 1
PIER 1
PIER 2
ELEVATION
Scale : 1" = 15'
40'-0" Roadway
20'-0"
20'-0"
℄ Survey & ℄ Roadway
Profile Grade
.06'/Ft
8½" Slab
Drop Haunch at Drain
8" ⌀ Air Porthole (Typ)
5 Precast Conc. Modified Type IV (72-8) Beams @ equal spaces
Intermediate Diaphragm, Steel Sway Bracing in Concrete Diaph. (Typ)
TYPICAL SECTION THRU DECK (Looking Ahead) Scale : ¼" = 1'-0"
CONCRETE
110'-110'-110'-110' Prestressed Continuous for Live Load 40'-0" Roadway, 1'-7¾" Bar 48' Shoulders at Bridge
REVISION
DATE
6.26.89



REVISION	DATE	DESCRIPTIONS	BY	CHECKED
1	6/26/89	Approx Average Rock Line	NET	DGM

GRAPHIC SCALE

US ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE TENNESSEE

Designed by: DGM
Drawn by: NET
Checked by: CPK Jr
Approved by:

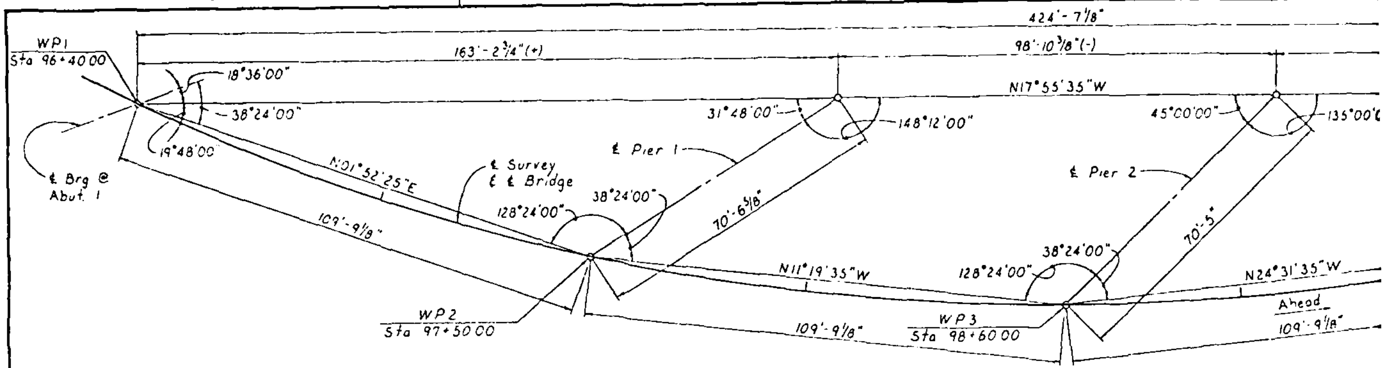
UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
LAYOUT
KENTUCKY HWY 72
OVER DOWNSTREAM PORTAL

Date:
Sheet _ of _
Scale: AS NOTED
Drawing Number: OIA-81/75.1
Record Drawing as constructed dated

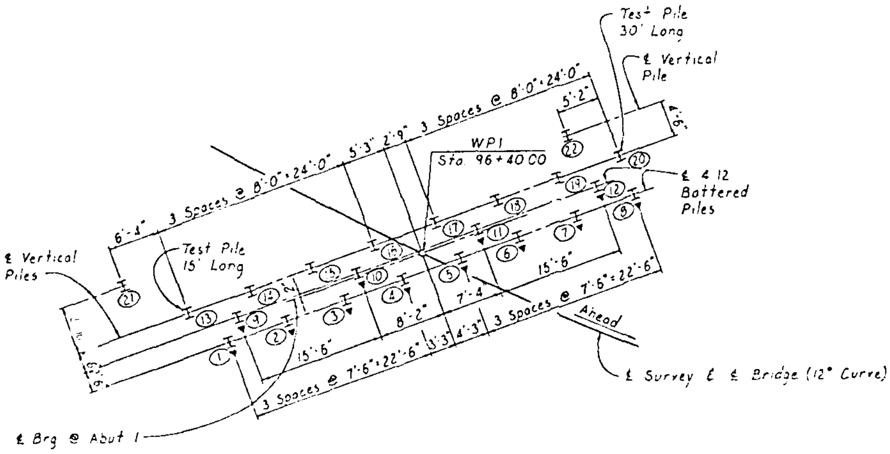
KYDOH DRWG NO 21912

PLATE G-1

20



SUBSTRUCTURE LAYOUT
Scale 1" = 15'-0"



PILE LAYOUT – ABUTMENT 1
Scale 1/8" = 1'-0"

NOTE

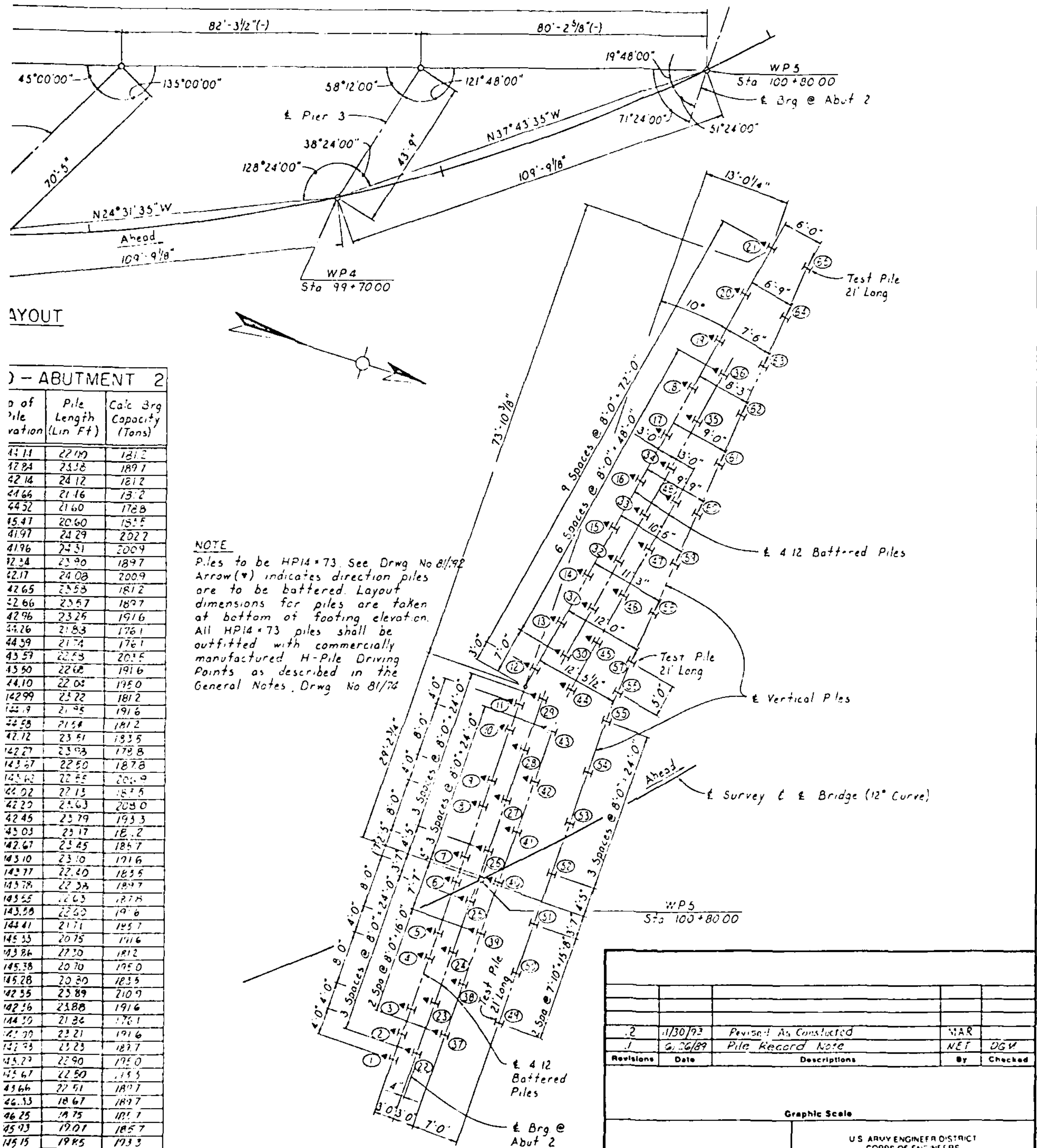
After piles have been driven, the Contractor shall record for each pile, the tip of pile elevation as driven, the length of pile in place and the calculated bearing capacity and shall return one blueprint copy of this sheet with this data to the Contracting Officer so that the data may be recorded on the original plans. Length of piles in place shown hereon are the actual lengths of piles in the finished structure below cut-off elevation and are not necessarily pay items. This pile record does not replace other records of piles required to be kept and submitted by the Contractor. This data is to be verified by the Resident Engineer.

PILE RECORD – ABUTMENT 1

Pile No	Pile Cut-off Elevation	Tip of Pile Elevation	Pile Length (Lin Ft)	Calc Brg Capacity (Tons)
1	1176.460	1160.18	17.21	212.7
2	"	1160.57	16.75	193.5
3	"	1158.88	18.55	199.5
4	"	1157.87	19.61	216.7
5	"	1157.87	19.61	213.6
6	"	1156.34	21.23	205.8
7	"	1154.07	23.62	222.8
8	"	1151.86	25.95	178.8
9	"	1160.87	16.45	198.1
10	"	1155.31	19.15	202.2
11	"	1156.95	20.58	222.8
12	"	1151.61	26.21	185.7
13	"	1159.42	16.98	173.3
14	"	1158.53	17.93	173.3
15	"	1158.36	18.10	173.3
16	"	1157.17	19.29	178.8
17	"	1153.05	23.41	187.7
18	"	1151.00	25.38	193.1
19	"	1147.79	28.67	210.0
20	"	1147.59	28.87	176.1
21	"	1158.85	17.61	195.0
22	"	1147.08	29.38	193.3

PILE RECORD – ABUTMENT 2

Pile No	Pile Cut-off Elevation	Tip of Pile Elevation	Pile Length (Lin Ft)	Calc Brg Capacity (Tons)
1	1165.00	1144.14	22.09	181.2
2	"	1147.84	23.38	189.7
3	"	1142.14	24.12	181.2
4	"	1144.66	21.46	181.2
5	"	1144.52	21.60	178.8
6	"	1145.47	20.60	183.5
7	"	1141.97	24.29	202.2
8	"	1141.96	24.31	200.9
9	"	1142.34	23.90	189.7
10	"	1142.17	24.08	200.9
11	"	1142.65	23.58	181.2
12	"	1142.66	23.57	189.7
13	"	1142.96	23.25	191.6
14	"	1144.26	21.83	176.1
15	"	1144.39	21.74	176.1
16	"	1143.59	22.58	203.5
17	"	1143.50	22.68	191.6
18	"	1144.10	22.04	195.0
19	"	1142.99	23.22	181.2
20	"	1144.19	21.95	191.6
21	"	1144.58	21.54	181.2
22	"	1142.72	23.51	183.5
23	"	1142.27	23.93	178.8
24	"	1143.67	22.50	187.8
25	"	1143.62	22.55	206.9
26	"	1144.02	22.15	183.5
27	"	1142.20	23.63	208.0
28	"	1142.45	23.79	193.3
29	"	1143.03	23.17	181.2
30	"	1142.67	23.45	185.7
31	"	1143.10	23.10	191.6
32	"	1143.77	22.40	183.5
33	"	1143.78	22.38	189.7
34	"	1143.55	22.63	187.8
35	"	1143.58	22.60	191.6
36	"	1144.41	21.71	185.7
37	"	1145.35	20.75	191.6
38	"	1143.86	22.30	181.2
39	"	1145.38	20.70	195.0
40	"	1145.28	20.80	183.5
41	"	1142.35	23.89	210.9
42	"	1142.36	23.88	191.6
43	"	1144.30	21.84	176.1
44	"	1144.20	22.21	191.6
45	"	[illegible]	23.25	187.7
46	"	1143.29	22.90	195.0
47	"	1143.67	22.50	193.3
48	"	1143.66	22.51	189.7
49	"	1146.33	18.67	189.7
50	"	1146.25	18.75	185.7
51	"	1145.93	19.07	185.7
52	"	1145.15	19.85	193.3
53	"	1144.28	20.72	183.5
54	"	1144.62	20.38	181.2
55	"	1143.43	21.57	181.2
56	"	1143.75	21.25	181.2
57	"	1142.00	22.99	189.7
58	"	1143.75	21.25	181.2
59	"	1143.63	21.37	187.7
60	"	1144.56	20.44	176.1
61	"	1144.22	20.78	191.6
62	"	1145.62	19.38	191.6
63	"	1144.71	20.29	191.6
64	"	1144.85	20.15	185.7
65	"	1144.70	20.30	202.2



AYOUT

) – ABUTMENT 2		
o of ile vation	Pile Length (Lin Ft)	Calc Brg Capacity (Tons)
43.11	22.00	181.2
42.84	23.38	189.7
42.14	24.12	181.2
44.66	21.16	181.2
44.52	21.60	176.8
45.47	20.60	183.5
41.97	24.29	202.2
41.96	24.31	200.9
42.34	23.90	189.7
42.17	24.08	200.9
42.65	23.58	181.2
42.66	23.57	189.7
42.96	23.26	191.6
44.26	21.83	176.1
44.39	21.74	176.1
43.57	22.58	203.5
43.50	22.62	191.6
44.10	22.02	195.0
142.99	23.22	181.2
[illegible]	21.95	191.6
44.58	21.54	181.2
42.12	23.51	193.5
142.27	23.93	178.8
143.67	22.50	187.8
143.62	22.55	204.9
44.02	22.13	183.5
42.20	23.63	208.0
42.45	23.79	193.3
43.03	23.17	181.2
142.67	23.45	185.7
143.10	23.10	191.6
143.77	22.40	183.5
143.78	22.38	189.7
143.55	22.63	187.8
143.58	22.60	191.6
144.41	21.71	195.7
145.33	20.75	191.6
143.86	22.30	181.2
145.38	20.70	195.0
145.28	20.80	183.5
142.55	23.89	210.9
142.56	23.88	191.6
144.30	21.84	176.1
142.99	23.21	191.6
142.93	23.23	187.7
143.27	22.90	195.0
143.67	22.50	193.5
43.66	22.51	189.7
46.33	18.67	189.7
46.25	18.75	185.7
45.93	19.01	185.7
145.15	19.85	193.3
144.78	20.72	183.5
144.62	20.38	181.2
143.43	21.57	181.2
143.75	21.25	181.2
142.00	22.91	189.7
143.75	21.75	181.2
143.63	21.37	189.7
44.56	20.44	176.1
44.72	20.18	191.6
145.62	17.38	191.6
44.11	20.27	191.6
44.85	20.15	185.7
44.70	20.30	202.2

NOTE
Piles to be HP14×73. See Drwg No 81/92. Arrow (▼) indicates direction piles are to be battered. Layout dimensions for piles are taken at bottom of footing elevation. All HP14×73 piles shall be outfitted with commercially manufactured H-Pile Driving Points as described in the General Notes, Drwg No 81/76.

PILE LAYOUT – ABUTMENT 2
Scale 1/8" = 1'-0"

Revisions	Date	Descriptions	By	Checked
2	11/30/93	Revised As Constructed	MAR	
1	6/26/89	Pile Record Note	NET	DGV

Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE TENNESSEE

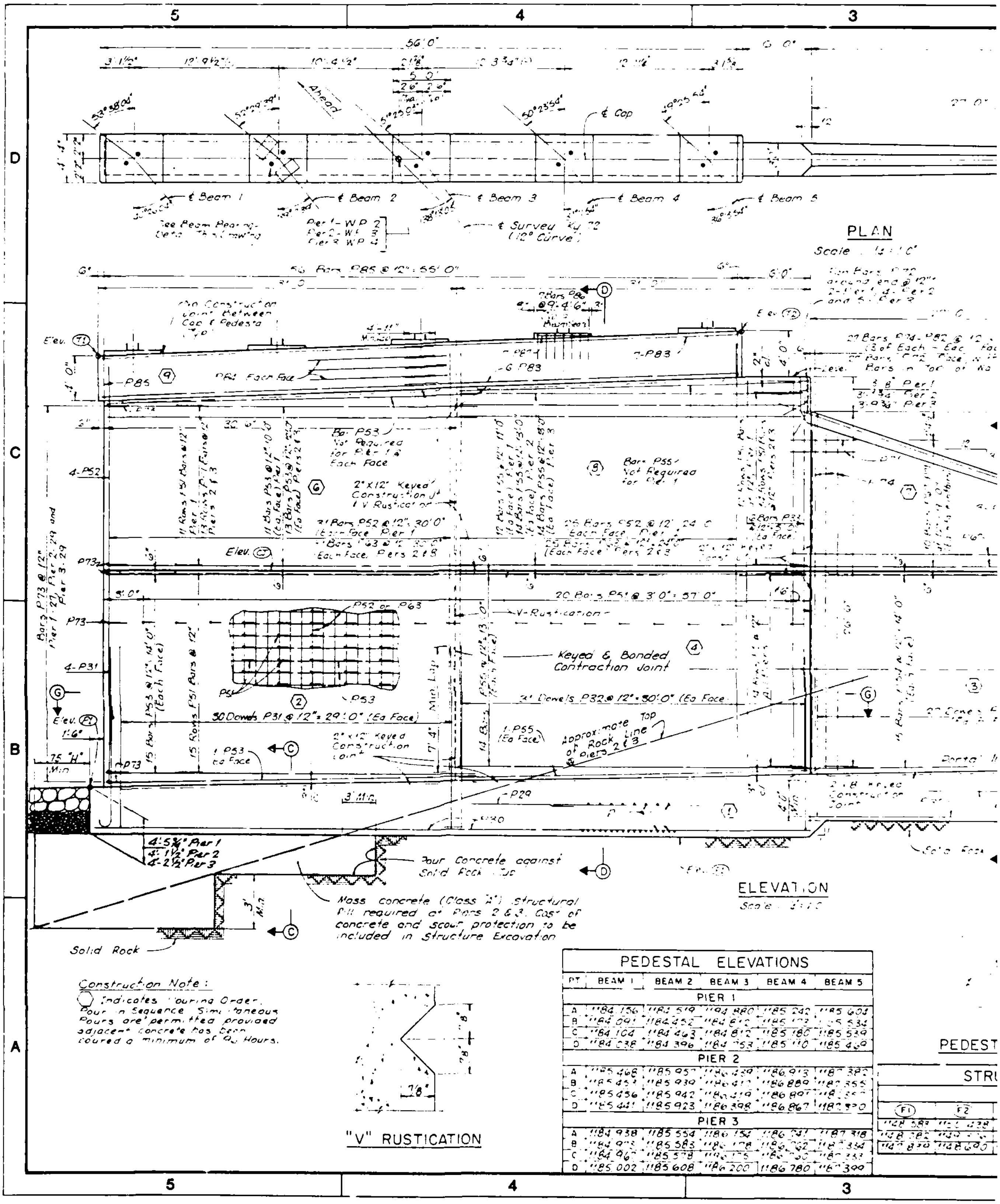
Designed by: DGM
Drawn by: JBB
Checked by: DGM
Approved by: [signature]

US Army Corps of Engineers Nashville District

UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
SUBSTRUCTURE LAYOUT & PILE RECORD
KENTUCKY HWY. 72
OVER DOWNSTREAM PORTAL

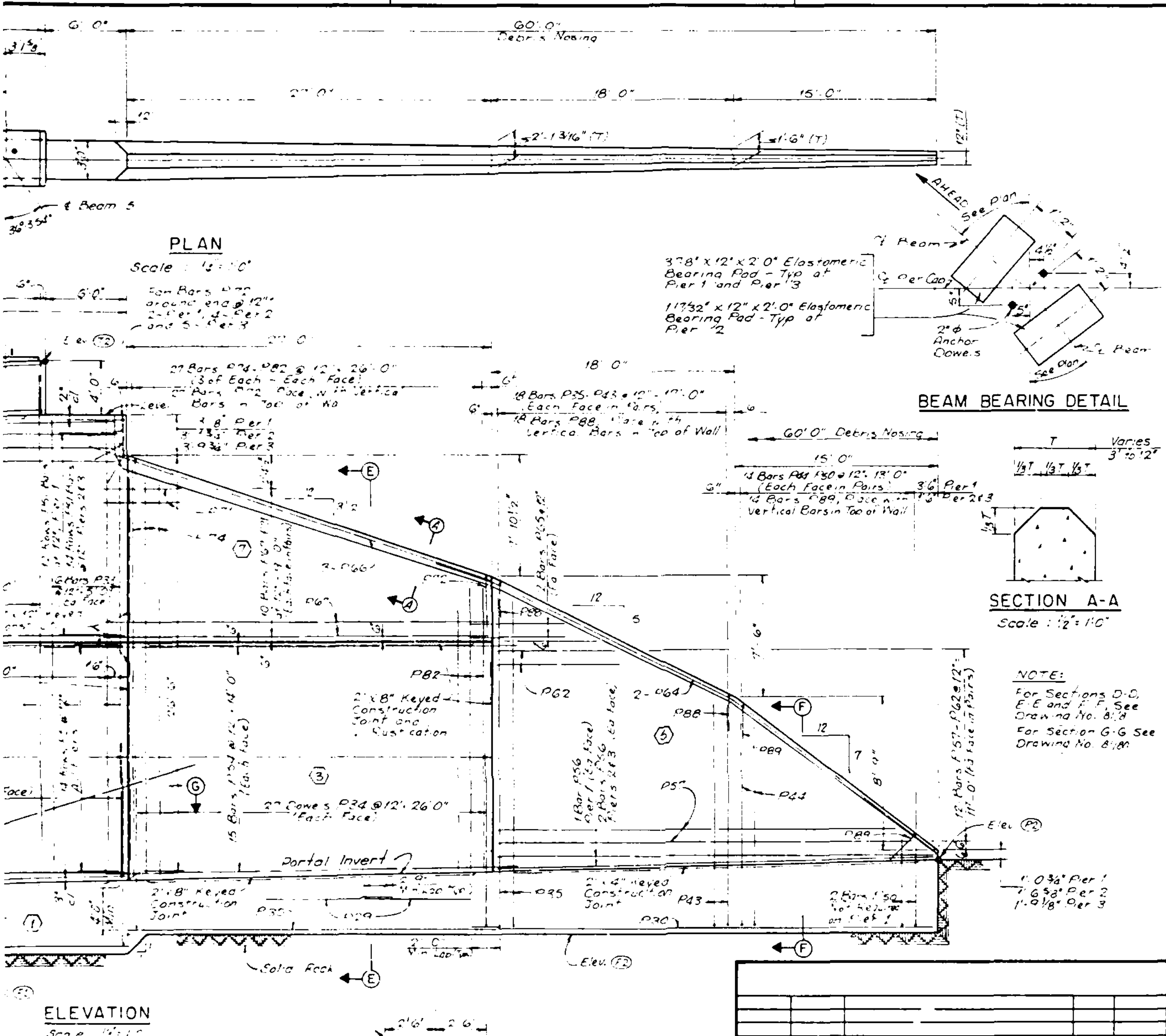
Date:
Sheet ___ of ___
Scale: As Noted
Drawing Number: 01A-81/76.2
Record Drawing as constructed dated

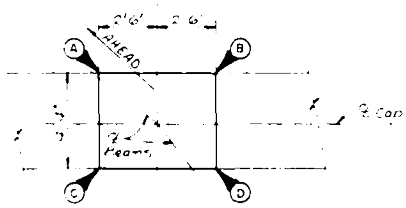
PLATE G-2



Construction Note: ⬡ Indicates Pouring Order. Pour in Sequence. Simultaneous Pours are permitted provided adjacent concrete has been poured a minimum of 72 Hours.

PEDESTAL ELEVATIONS					
PT	BEAM 1	BEAM 2	BEAM 3	BEAM 4	BEAM 5
PIER 1					
A	1184 156	1184 519	1184 880	1185 242	1185 603
B	1184 091	1184 452	1184 8[illegible]	1185 [illegible]	[illegible]5 534
C	1184 104	1184 463	1184 812	1185 180	1185 539
D	1184 038	1184 396	1184 753	1185 110	1185 469
PIER 2					
A	1185 468	1185 957	1186 439	1186 913	1187 382
B	1185 45[illegible]	1185 930	1186 41[illegible]	1186 889	1187 355
C	1185 456	1185 942	1186 419	1186 897	1187 3[illegible]
D	1185 441	1185 923	1186 398	1186 867	1187 370
PIER 3					
A	1184 938	1185 554	1186 154	1186 741	1187 318
B	1184 973	1185 583	1186 178	1186 762	1187 334
C	1184 967	1185 578	1186 175	1186 [illegible]	1187 333
D	1185 002	1185 608	1186 200	1186 780	1187 390





PEDESTAL ELEVATION LOCATIONS

ELEVATIONS		
BEAM 3	BEAM 4	BEAM 5
IER 1		
1194 880	1185 242	1185 604
1184 811	[illegible]	1185 534
1184 812	1185 180	1185 539
1184 753	1185 110	1185 469
IER 2		
1186 439	1186.913	1187 382
[illegible]	1186 889	1187 355
1186.419	1186 891	[illegible]
1186 398	1186 867	1187 330
IER 3		
1186 154	1186 741	1187 318
1186 178	1186.762	1187 334
[illegible]	[illegible]	[illegible]
1186 200	1186 780	1187 399

STRUCTURE CONTROL POINTS

ELEVATIONS							LOCATION
F1	F2	P1	P2	CJ	T1	T2	
1148.583	1150.438	1153.060	1155.750	1169.063	1183.583	1185.203	PIER 1
1148.382	[illegible]	1152.510	1154.200	1168.002	1184.882	1187.023	PIER 2
1147.830	1148.690	1152.045	1153.300	1167.310	1184.339	1187.000	PIER 3

Revisions	Date	Description	By	Checked
1	31 AUG 89	ADDED KYDOH DWG NO.	PNB	

Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE TENNESSEE

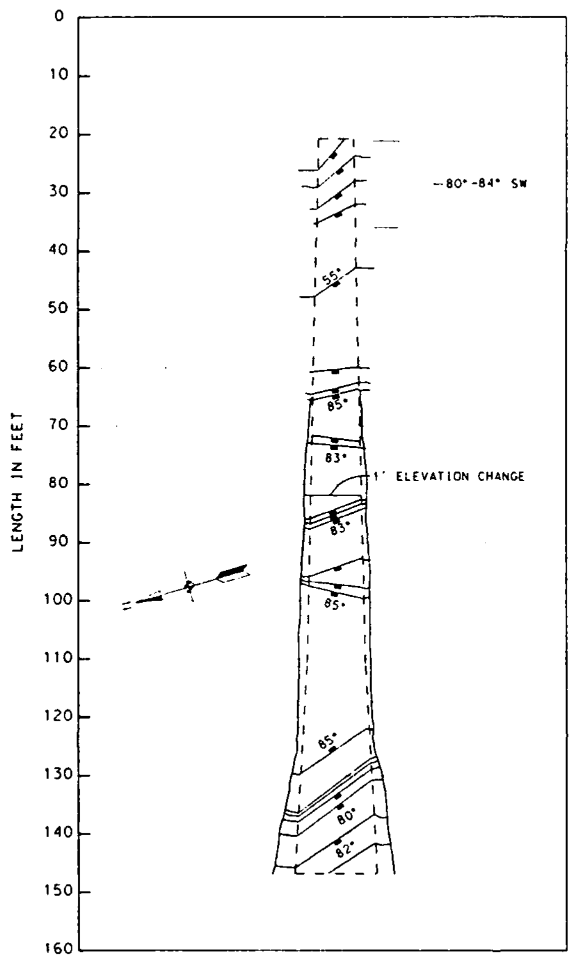
UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
PIER 1, PIER 2 AND PIER 3
KENTUCKY HWY 72
OVER DOWNSTREAM PORTAL

Designed by: CPK Jr
Drawn by: NET/BSB
Checked by: DGM
Approved by:
Date:
Sheet __ of __
Scale: AS NOTED
Drawing Number: QIA-81/79 1
Record Drawing as constructed dated

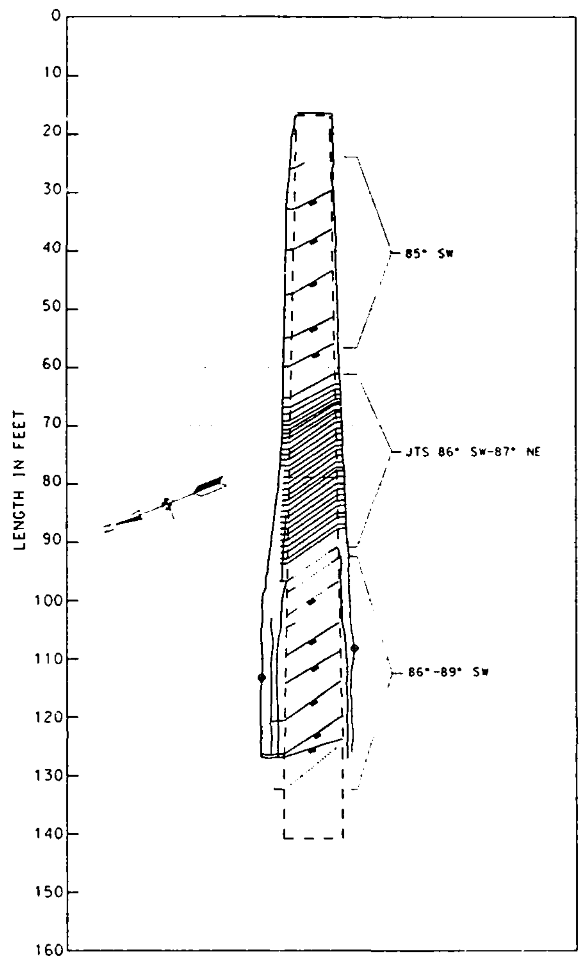
KYDOH DRWG NO 21912

PLATE G-3

5	4	3



PIER 3



PIER 2

LEGEND

- ● HORIZONTAL BEDDING PLANE
- 65 JOINT WITH DIP INDICATED. NOT ALL JOINT SYMBOLS AND DIPS ARE SHOWN DUE TO SPACE LIMITATIONS. VERY CLOSELY SPACED JOINT ZONES ARE BRACKETED WITH DIPS NOTED.

NOTES:

1. SILTSTONE BEDROCK FOUNDATION IS MOD TO SLIGHTLY WEATHERED, MASSIVE TO
2. JOINTS ARE TYPICALLY HIGH ANGLE (AS MODERATELY SPACED, TIGHT, CLEAN OR SOFT SILTY CLAY, AND NOT HEALED.
3. BEDDING PLANES ARE TIGHT TO SLIGHTI SLIGHTLY ROUGH, AND HORIZONTAL.
4. DASHED LINES REPRESENT PERIMETER A EXCAVATION. ADJACENT AREAS OUTSIDE VERTICAL SIDES OF THE EXCAVATION AS PLANAR SURFACES.
5. SEE PLATE A-2 FOR GENERAL NOTES.
6. SEE PLATES A-3 THRU A-5 FOR EXPLAN

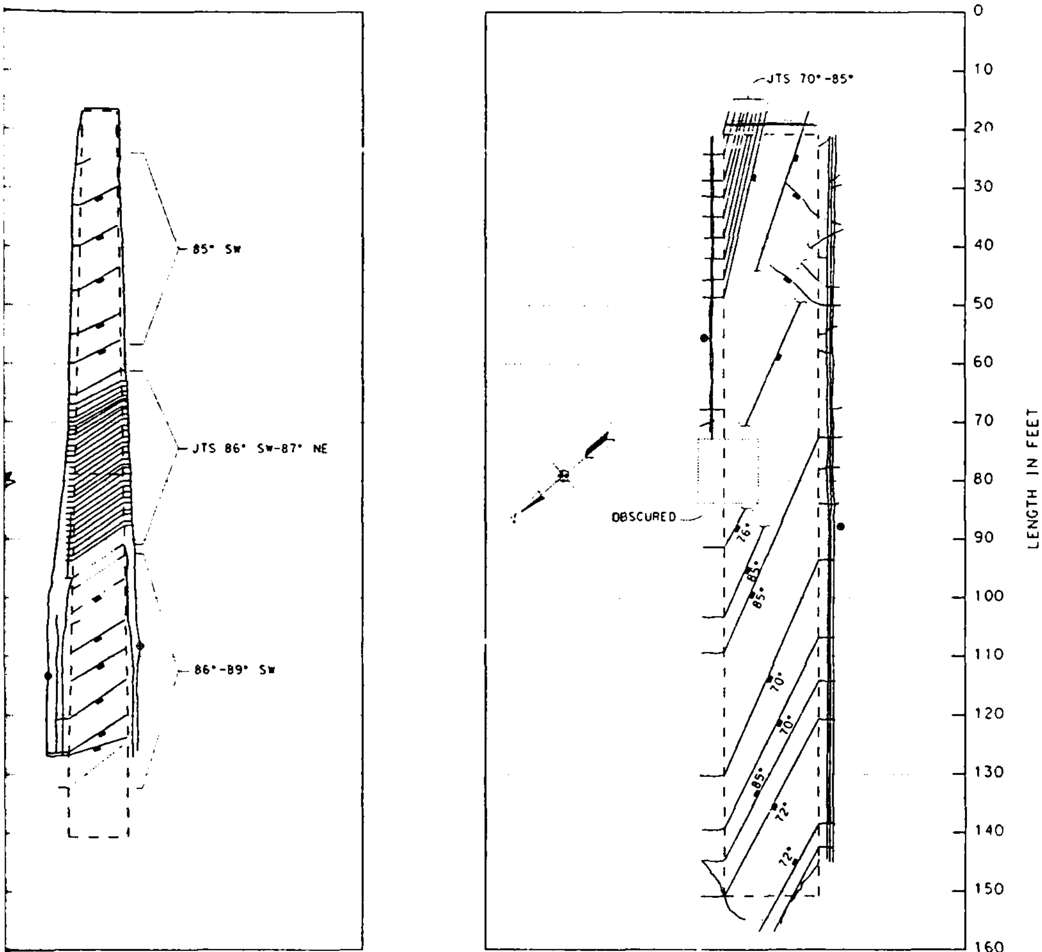
5	4	3

1-4

DRILLING LOG | DIVISION ORD

1. PROJECT
HARLAN DIVERSION PROJECT
2. LOCATION
Highway 38 Bridge Abutment No. 1

INSTALLATION
ORD
SHEET 1 OF 1 SHEETS
10. SIZE AND TYPE OF BIT 48 in Auger/coring tool
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
MSL
12. MANUFACTURER'S DESIGNATION OF DRILL



PIER 2

PIER 1

NOTES:

1. SILTSTONE BEDROCK FOUNDATION IS MODERATELY HARD, UNWEATHERED TO SLIGHTLY WEATHERED, MASSIVE TO MEDIUM BEDDED, DARK GRAY.
2. JOINTS ARE TYPICALLY HIGH ANGLE (AS SHOWN) VERY WIDELY TO MODERATELY SPACED, TIGHT, CLEAN OR FILLED WITH UP TO 0.3' SOFT SILTY CLAY, AND NOT HEALED.
3. BEDDING PLANES ARE TIGHT TO SLIGHTLY OPEN, CLEAN, SMOOTH TO SLIGHTLY ROUGH, AND HORIZONTAL.
4. DASHED LINES REPRESENT PERIMETER AT BOTTOM OF FOOTING EXCAVATION. ADJACENT AREAS OUTSIDE DASHED LINES REPRESENT VERTICAL SIDES OF THE EXCAVATION FOLDED BACK AND MAPPED AS PLANAR SURFACES.
5. SEE PLATE A-2 FOR GENERAL NOTES.
6. SEE PLATES A-3 THRU A-5 FOR EXPLANATION OF DESCRIPTIVE TERMS.

10' 5 0 10 20 FT

Graphic Scale

REVISIONS				
REV.	DESCRIPTION	DATE	BY	APPROVED

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

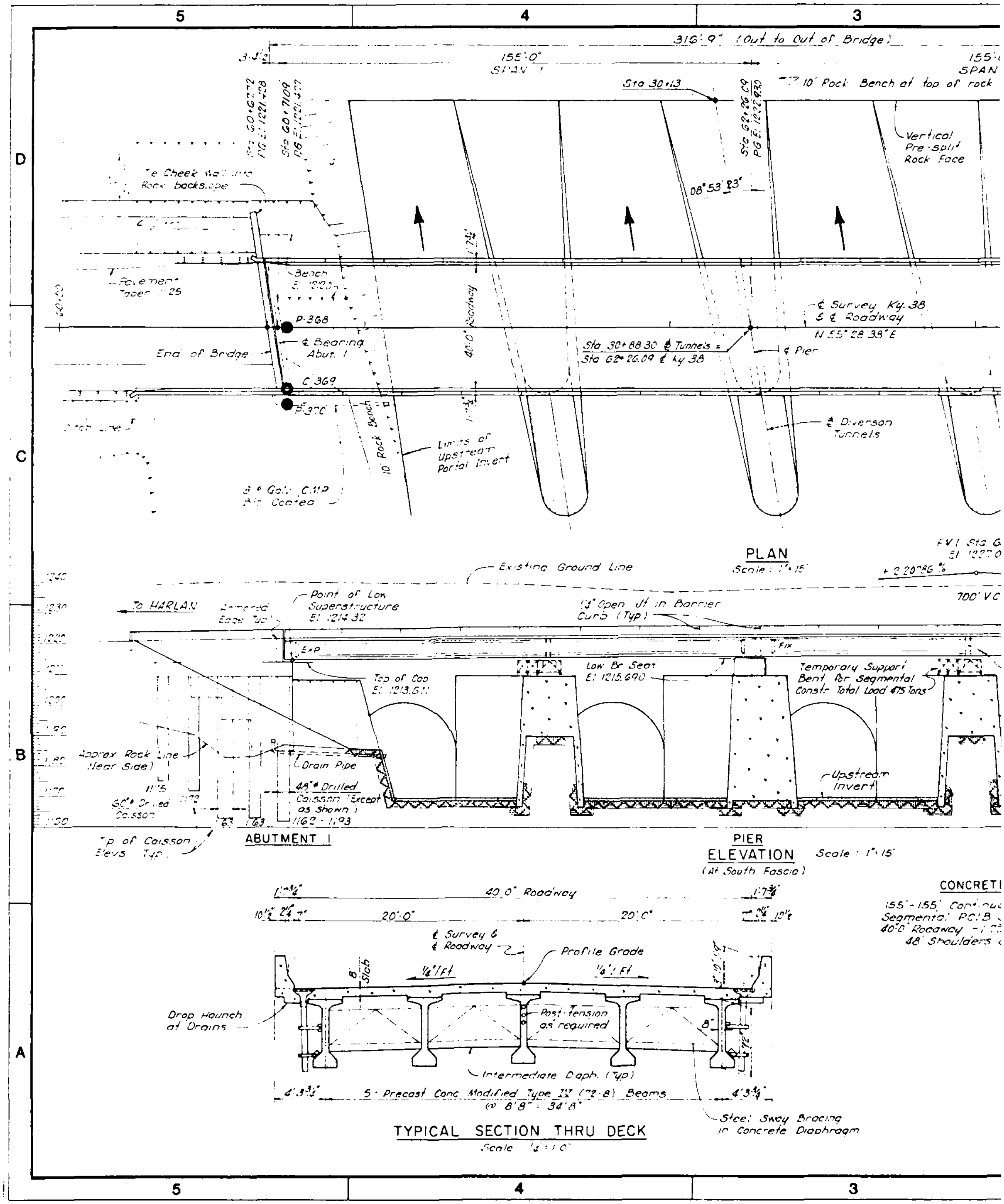
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION TUNNELS
HIGHWAY 72 BRIDGE
PIER FOUNDATIONS

Drawn By: C.A.G.
Checked By: P.R.
P.R.
Approved By:
Date: FEB 1994
Scale: 1"=10'
Record Drawing as constructed dated
Drawing Number: Q1A-4/398

PLATE G-4

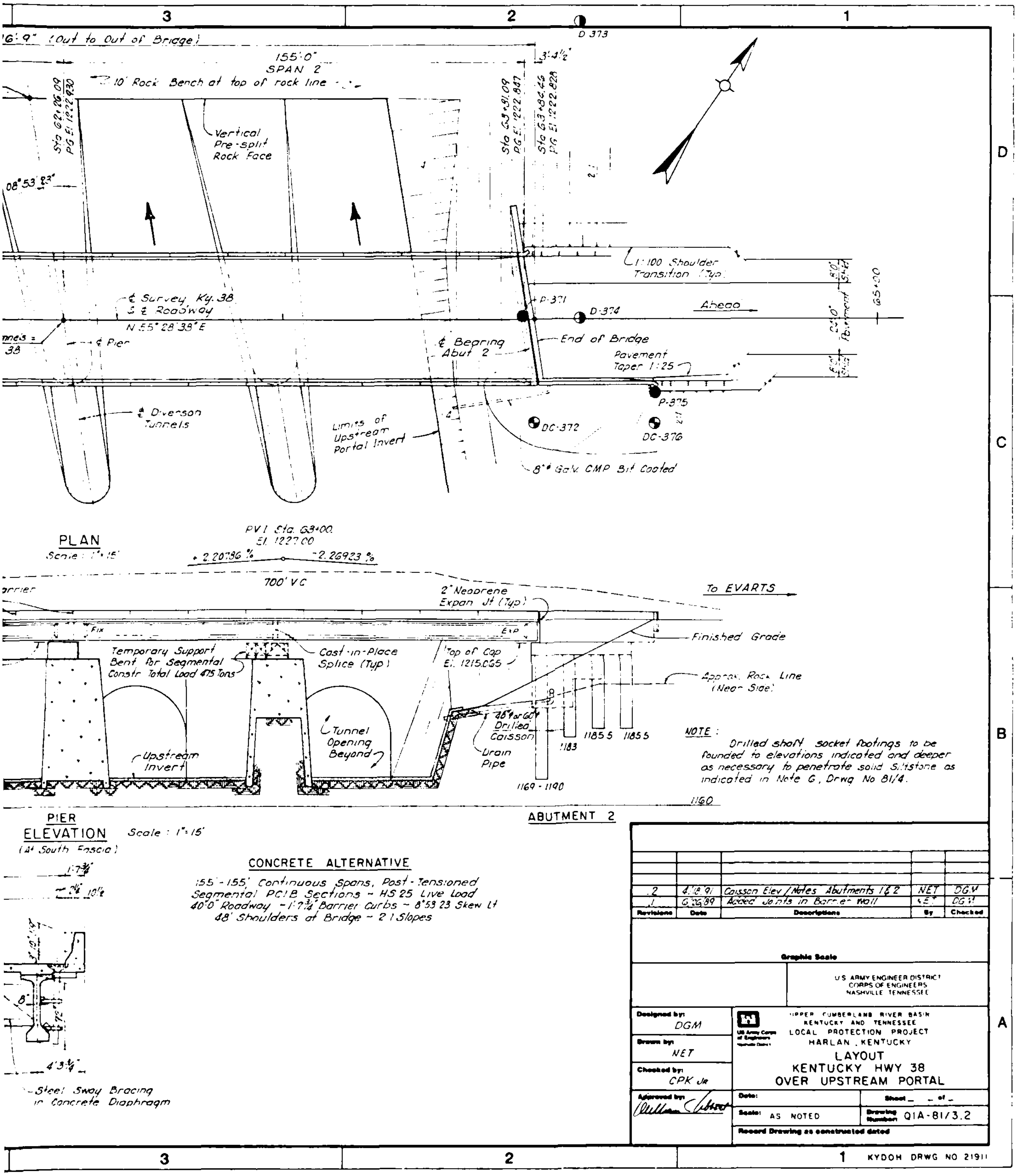
Appendix H - Highway 38 and Bridge

Plate No.	Drawing No.	Description
H-1	Q1A-81/3.2	Bridge Layout
H-2	Q1A-81/4.3	Caisson Details
H-3	Q1A-4/399	Boring Logs
H-4	Q1A-4/400	Boring Logs
H-5 thru 19	----	Caisson Hole Maps



Hole No. CA 1-8

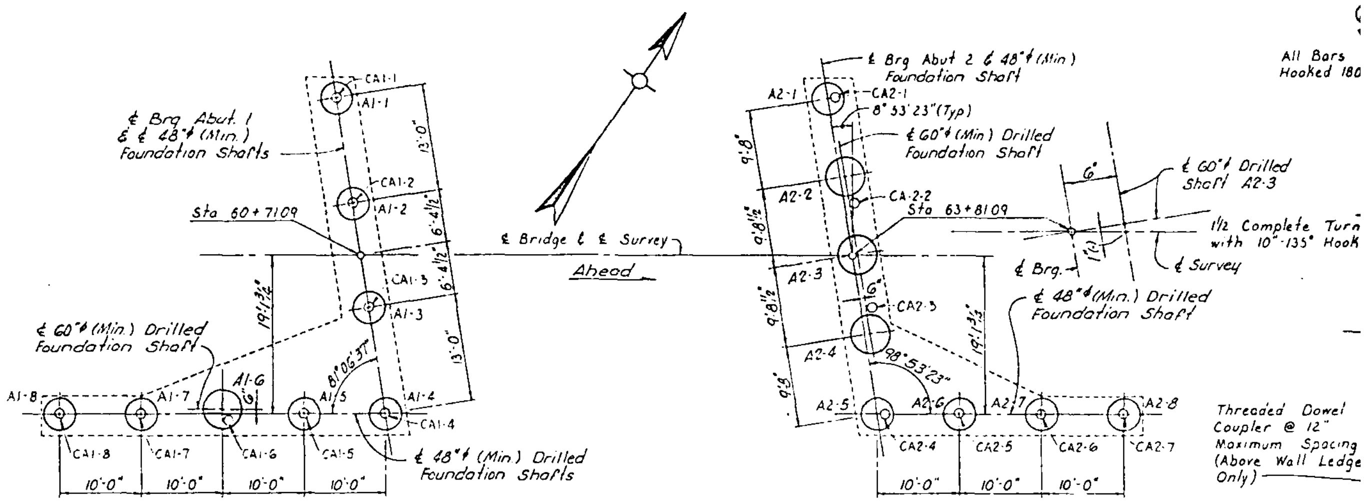
DRILLING LOG	Division ORD	INSTALLATION NED	SHEET 1 OF 1 SHEETS
1. PROJECT HARLAN DIVERSION PROJECT		10. SIZE AND TYPE OF BIT 4B in ROCK AUGER	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL	



(Out to Out of Bridge)
155'-0"
SPAN 2
10' Rock Bench at top of rock line
Vertical Pre-split Rock Face
Sta 63+81.09 PG El 1222.847
Sta 63+84.66 PG El 1222.828
D 373
1:100 Shoulder Transition (Typ)
℄ Survey Ky.38 & ℄ Roadway
N 55° 28' 38" E
P-371
D-374
Ahead
End of Bridge
℄ Bearing Abut 2
Pavement Taper 1:25
P-375
℄ Pier
℄ Diversion Tunnels
Limits of Upstream Portal Invert
DC-372
DC-376
8" Galv. CMP Bit Coated
PLAN
PVI Sta 63+00
El 1227.00
+2.20786 %
-2.26923 %
700' VC
2" Neoprene Expan Jt (Typ)
To EVARTS
Finished Grade
Temporary Support Bent for Segmental Constr Total Load 475 Tons
Cast-in-Place Splice (Typ)
Top of Cap El 1215.065
Approx. Rock Line (Near Side)
Tunnel Opening Beyond
Upstream Invert
Drilled Caisson
Drain Pipe
1169 - 1190
1183
1185.5
1185.5
1160
NOTE: Drilled shaft socket footings to be founded to elevations indicated and deeper as necessary to penetrate solid Siltstone as indicated in Note G, Drwg No 81/4.
PIER
ELEVATION Scale: 1"=15'
(At South Fascia)
ABUTMENT 2
CONCRETE ALTERNATIVE
155'-155' Continuous Spans, Post-Tensioned Segmental PCIB Sections ~ HS 25 Live Load
40'0" Roadway ~ 1'-7¾" Barrier Curbs ~ 8°53'23" Skew Lt
48' Shoulders at Bridge ~ 2:1 Slopes
Steel Sway Bracing in Concrete Diaphragm
2 | 4/18/91 | Caisson Elev/Notes Abutments 1 & 2 | NET | DGM
1 | 6/26/89 | Added Joints in Barrier Wall | NET | DGM
Revisions | Date | Descriptions | By | Checked
Graphic Scale
U.S. ARMY ENGINEER DISTRICT CORPS OF ENGINEERS NASHVILLE TENNESSEE
Designed by: DGM
Drawn by: NET
Checked by: CPK Jr
Approved by:
UPPER CUMBERLAND RIVER BASIN KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
LAYOUT
KENTUCKY HWY 38
OVER UPSTREAM PORTAL
Scale: AS NOTED
Drawing Number Q1A-81/3.2
Record Drawing as constructed dated
KYDOH DRWG NO 21911

PLATE H-I

5	4	3



DRILLED SHAFT LAYOUT
AND PROOF-TEST CORE HOLE LOCATIONS

DRILLED SHAFT FOUNDATION SCHEDULE																FOR INFO ONLY Design Quantities ⊕	
Drilled Shaft Mark	Shaft Dia (Min)	Vertical Reinforcement			Top of Drilled Shaft Elev (A)	Bottom of Wall Ledge Elev (B)	Top of Rock Elevation (C)		Bottom of Drilled Shaft-Elevation (D)		Design-Drilled Shaft Length		Payment Lengths			Drilled Shaft Concrete (Cu Yds)	Drilled Shaft Stl. Reinf (Lbs)
		No	Size	Cutoff Elevation			Design	Actual	Design	Actual	Over-burden(Ft)	Rock (Ft)	Over-burden(Ft)	Rock (Ft)			
A1-1	48"	12	#11	1212.67	1209.67	1206.671	1208.3	1209.7	1193.0	1193.2	—	16.7	0.0	16.5		7.7	1708
A1-2	48"	12	#11	1212.67	1209.67	1199.671	1209.7	1209.7	1187.0	1188.7	—	22.7	0.0	21.0		10.3	2177
A1-3	48"	12	#11	1212.67	1209.67	1184.671	1201.6	1202.7	1174.0	1174.2	8.1	27.6	7.0	28.5		15.8	3195
A1-4	48"	12	#11	1212.67	1209.67	1184.671	1188.0	1191.7	1162.0	1162.4	21.7	26.0	18.0	29.3		21.4	4135
A1-5	48"	12	#11	1212.67	1209.67	1184.671	1183.0	1187.2	1163.0	1162.9	26.7	20.0	23.0	24.2		20.9	4060
A1-6	60"	27	#11	1212.67	1209.67	1195.671	1182.6	1185.7	1163.0	1163.2	27.1	19.6	25.0	22.5		33.5	8410
A1-7	48"	12	#11	1212.67	1209.67	1202.671	1190.0	1191.4	1172.0	1172.5	19.7	18.0	18.2	18.9		17.3	3355
A1-8	48"	12	#11	1212.67	1209.67	N A	1190.0	1189.2	1175.0	1174.2	19.7	15.0	20.5	15.0		16.1	3120
A2-1	48"	12	#11	1214.07	1211.07	1206.065/1196.565	1206.7	1211.8	1190.0	1189.2	4.3	16.7	0.0	21.8		9.5	4235
A2-2	60"	27	#11	1214.07	1211.07	1191.065	1200.0	1207.2	1178.0	1177.6	11.0	22.0	4.6	29.2		23.4	6190
A2-3	60"	27	#11	1214.07	1211.07	1190.065	1194.5	1202.2	1172.0	1171.1	16.5	22.5	9.0	30.2		27.6	7165
A2-4	60"	27	#11	1214.07	1211.07	1190.065	1191.5	1193.7	1169.0	1168.7	19.5	22.5	17.1	24.7		29.8	7655
A2-5	48"	12	#11	1214.07	1211.07	1193.065/1191.065	1195.5	1193.0	1179.0	1175.1	15.5	16.5	16.0	17.9		13.6	2915
A2-6	48"	12	#11	1214.07	1211.07	1193.065	1198.3	1196.3	1183.0	1181.3	12.7	15.3	14.8	15.0		12.5	2600
A2-7	48"	12	#11	1214.07	1211.07	1203.065	1200.8	1203.4	1185.5	1185.6	10.2	15.3	7.7	17.8		11.6	2400
A2-8	48"	12	#11	1214.07	1211.07	N A	1200.8	1201.0	1185.5	1185.0	10.2	15.3	11.5	15.5		11.9	2400

⊕ Based on Nominal Diameter Shafts

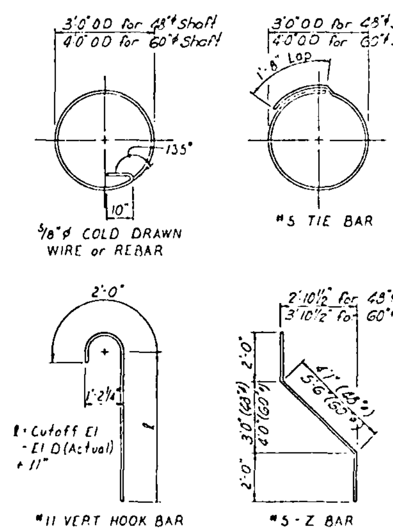
5/8"⌀ Spiral @ 8" Pitch, Full Length

DRILLED SHAFT NOTES

1. Foundation Shafts shall be Cast-in-Place Concrete, f_c = 4000 psi
2. Construction Joints not shown on Project Plans will require the approval of the Engineer prior to construction.
3. Spiral Reinforcement shall be 5/8"⌀ Cold Drawn Wire. The Ends of the Spiral shall be anchored with a 135° Hook around one of the Vertical Bars. Laps in Spiral Ties to be minimum distance of 2 turns with Spiral Tie anchored with 135° Hook.
4. For Reinforcement Cutoff Elevation, etc., see Schedule, this sheet
5. Fabrication of Reinforcing Steel Cage shall include Spacing Blocks so as to maintain proper Spiral Pitch and Vertical Steel Spacing.
6. Drilled shafts to be founded to elevations indicated and deeper as necessary to penetrate into solid rock a minimum of 15 feet for 48"⌀ shaft and 20 feet for 60"⌀ shaft. Solid rock is defined in Note 7 & shown on Typical Drilled Shaft Elevation.
7. For Drilling/Payment purposes, solid rock is defined as any material which cannot be drilled with a Conventional Earth Auger, and requires the use of Special Rock Augers, Core Barrels, Air Tools, Blasting and/or other methods of hand excavation.
8. After shafts are drilled, the Contractor in the presence of the Resident Engineer shall record for each shaft, the Top of Rock Elevation, Bottom of Shaft Elevations and Payment Lengths and shall return one blueprint copy of this completed sheet to the Engineer so the data may be recorded on the original plans. This Foundation Record does not replace other records of Drilled Shafts required to be kept and submitted by the Contractor.

1½ Complete with 10"-135

TYPICAL D



5	4	3

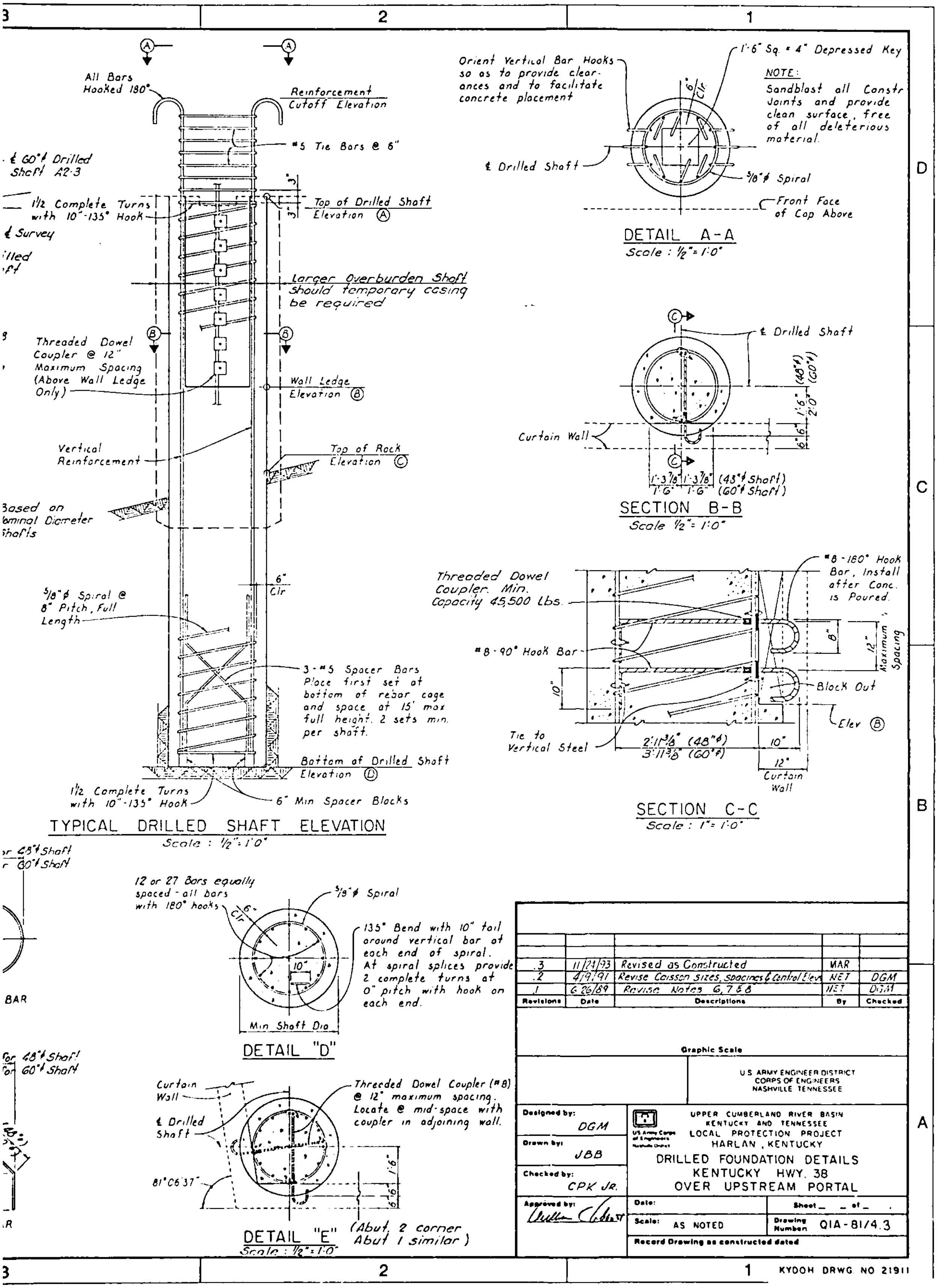
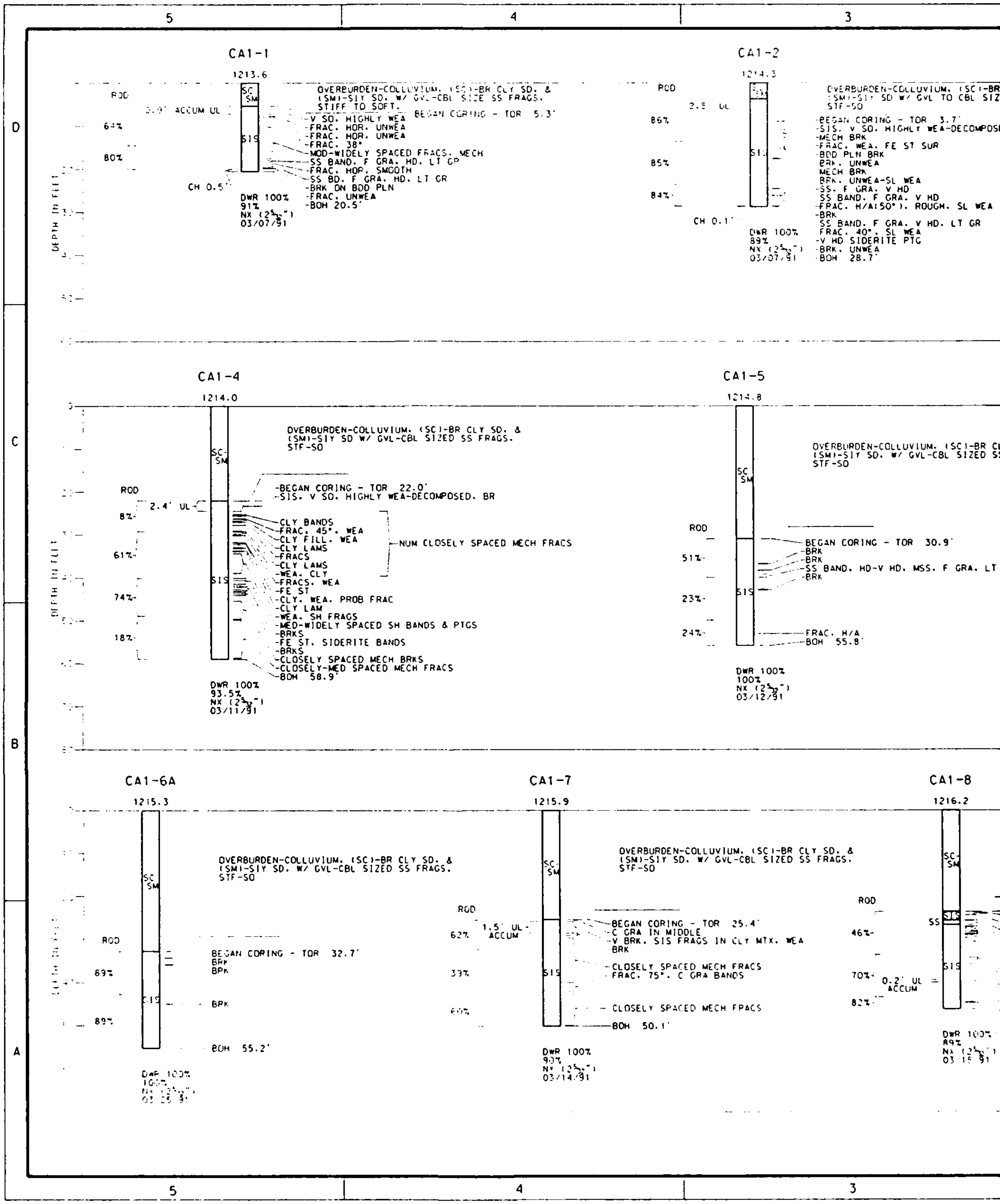


PLATE H-2

DRILLING LOG | DIVISION ORD | INSTALLATION NED | SHEET 1 of 1 SHEETS
PROJECT HARLAN DIVERSION PROJECT
2-3



DRILLING LOG

PROJECT

HARLAN DIVERSION PROJECT

LOCATION

A2-4

60° Rock Auger

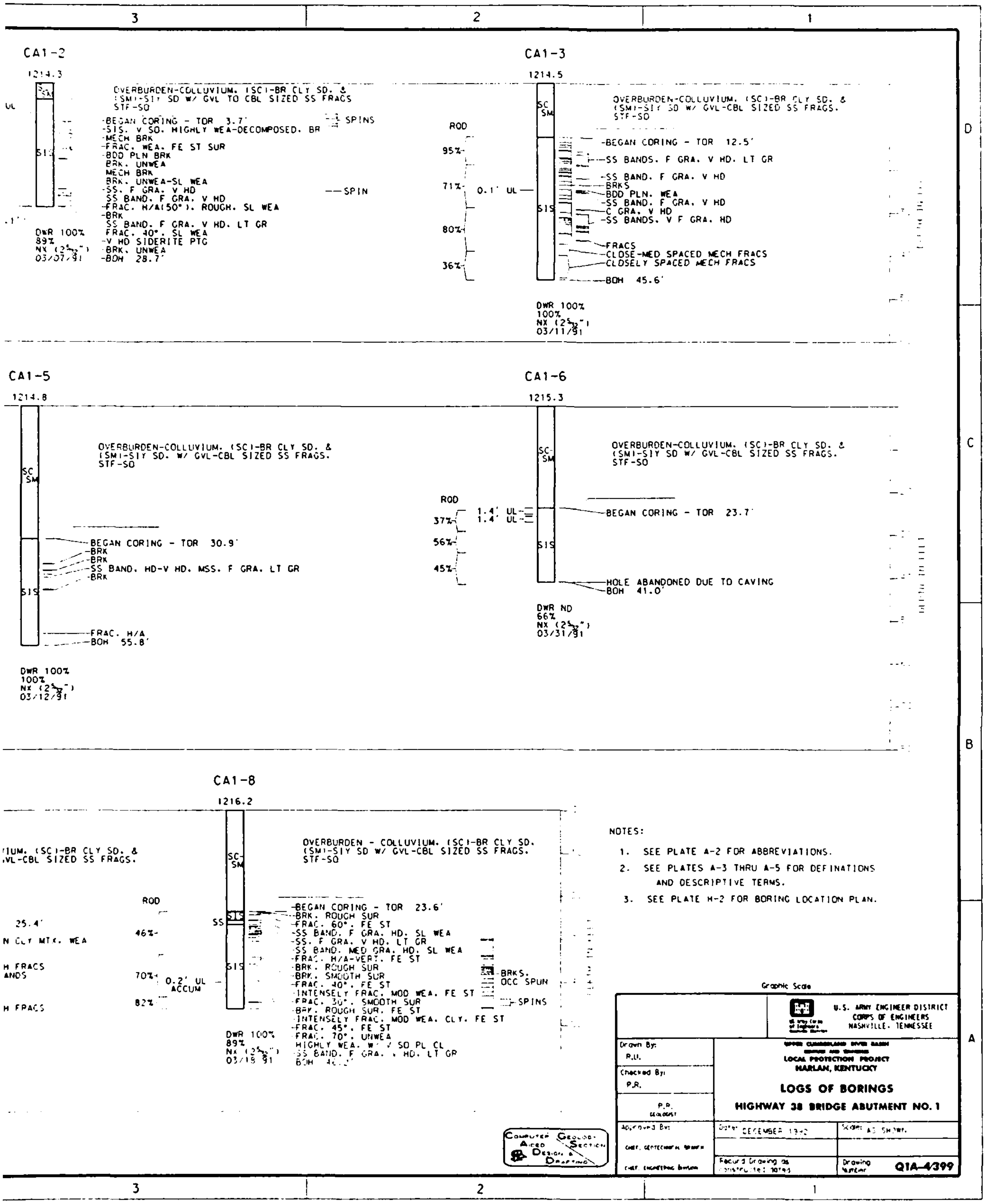
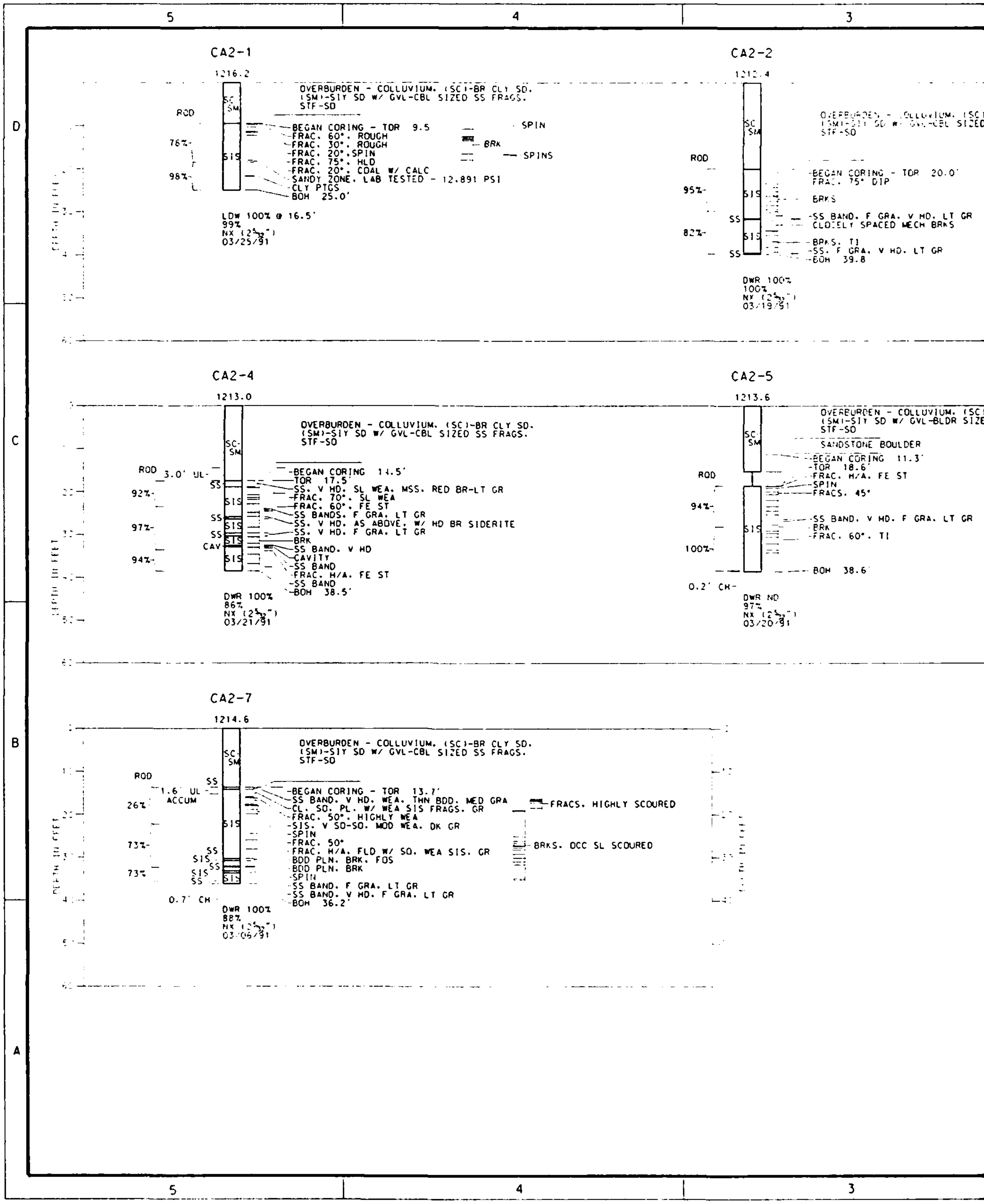


PLATE H-3

2)

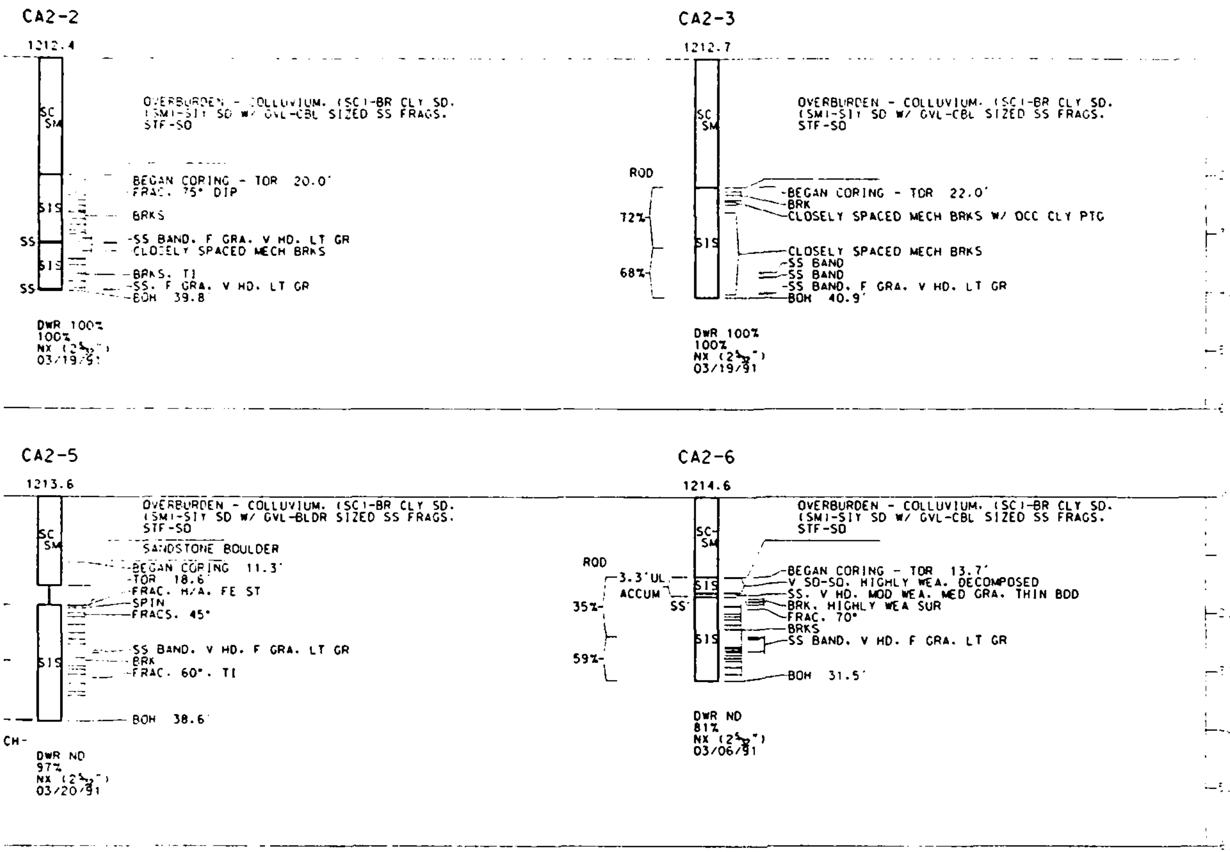
DRILLING LOG	DIVISION ORD	INSTALLATION NED	SHEET 1 OF / SHEETS
1. PROJECT HARLAN DIVERSION PROJECT		10. SIZE AND TYPE OF BIT	
2. LOCATION		11. DATUM FOR ELEVATION SHOWN MSL	

Hole No. CA 2-5



DRILLING LOG	DIVISION ORD	INSTALLATION NED	SHEET 1 OF 1 SHEETS
1. PROJECT HARLAN DIVERSION PROJECT		10. SIZE AND TYPE OF BIT	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL	

A2-6



NOTES:

1. SEE PLATE A-2 FOR ABBREVIATIONS.
2. SEE PLATES A-3 THRU A-5 FOR DEFINATIONS AND DESCRIPTIVE TERMS.
3. SEE PLATE H-2 FOR BORING LOCATION PLAN.

Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

Drawn By: R.U.
Checked By: P.R.

UPPER CUMBERLAND RIVER BASIN
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY

LOGS OF BORINGS

HIGHWAY 38 BRIDGE ABUTMENT NO. 2

Approved By:
CHIEF, GEOTECHNICAL BRANCH
CHIEF, ENGINEERING DIVISION

Date: DECEMBER 1991

Record Drawing as constructed dates

Drawing Number: Q1A-4400

COMPUTER AIDED DESIGN & DRAFTING
GEOLOGY SECTION

PLATE H-4

Hole No. A 1-1

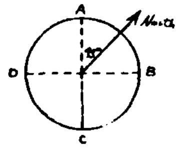
DRILLING LOG	DIVISION ORD	INSTALLATION NED	SHEET 1 of 1 SHEETS
1. PROJECT HARLAN DIVERSION PROJECT		10. SIZE AND TYPE OF BIT 48 in. Rock Auger	
2. LOCATION Highway 38 Bridge Abutment No. 1		11. DATUM FOR ELEVATION SHOWN MSL	
3. DRILLING AGENCY Hayes		12. MANUFACTURER'S DESIGNATION OF DRILL Hughes LDH 70	
4. HOLE NO. A 1-1		13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED —	
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES —	
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ___ DEG. FROM VERT.		15. ELEVATION GROUND WATER None	
		16. DATE HOLE STARTED 6-24-91 COMPLETED 6-24-91	
7. THICKNESS OF OVERBURDEN 0.0		17. ELEVATION TOP OF HOLE 1209.7	
8. DEPTH DRILLED INTO ROCK 16.5		18. TOTAL CORE RECOVERY FOR BORING —	
9. TOTAL DEPTH OF HOLE 16.5 (1193.2)		19. SIGNATURE OF INSPECTOR	

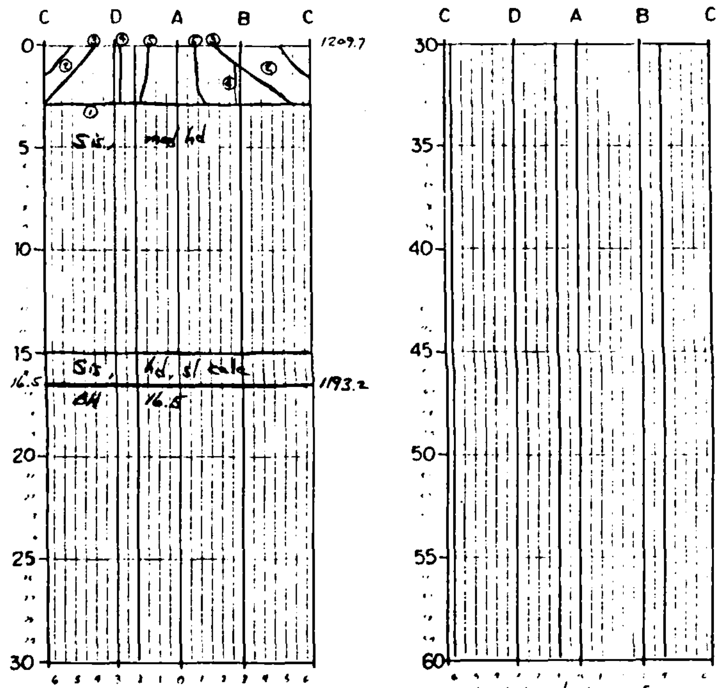
Caisson No.: CA1-1

Surface El: 1209.7

El TOR: 1209.7

BH 1193.2





A 5 ft deep jackhammer hole was drilled below bottom of caisson hole, from 16.5 to 21.5 ft. depth. No fractures or voids detected.

FEATURE NO.	DESCRIPTION
1	Bed pln, hor, ti
2	Jt filling, sa cl w/ ss frags, 0.5-2.0' th
3	Jt, N25E, 42SE, filled (See No. 2 above)
4	Jt, N55E, 77SE, filled w/ ½ in sa sy cl
5	Jt, N40E, 88SE, filled w/ ¼ in sa sy cl

REMARKS:

Line A-C is along caisson row alignment.
Bearing: N43W

Groundwater: None

Drill Time: 0' - 15' 3 hrs; 15 - 16.5 2½ hrs

Concrete Placed: 6-25-91

Plate H-5

Hole No. A 1-2

DRILLING LOG	DIVISION ORD	INSTALLATION NED	SHEET 1 of 1 SHEETS
1. PROJECT HARLAN DIVERSION PROJECT		10. SIZE AND TYPE OF BIT / 11. DATUM FOR ELEVATION SHOWN	

Hole No. CA 1-2

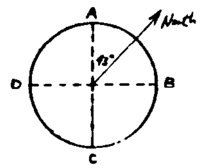
DRILLING LOG	DIVISION ORD	INSTALLATION NED	SHEET 1 of 1 SHEETS
1. PROJECT: HARLAN DIVERSION PROJECT		10. SIZE AND TYPE OF BIT: 48" Rock Auger	
2. LOCATION (Coordinates or Station): Highway 38 Bridge Abutment No.		11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL	
3. DRILLING AGENCY: Hayes		12. MANUFACTURER'S DESIGNATION OF DRILL: Hughes LDH 70	
4. HOLE NO. (As shown on drawing title and file number): A 1-2		13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED — UNDISTURBED —	
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE: [x] VERTICAL [ ] INCLINED ___ DEG. FROM VERT.		15. ELEVATION GROUND WATER: None	
		16. DATE HOLE: STARTED — COMPLETED 7-9-91	
7. THICKNESS OF OVERBURDEN: 0.0		17. ELEVATION TOP OF HOLE: 1209.7	
8. DEPTH DRILLED INTO ROCK: 21.0		18. TOTAL CORE RECOVERY FOR BORING: —	
9. TOTAL DEPTH OF HOLE: 21.0		19. SIGNATURE OF INSPECTOR	

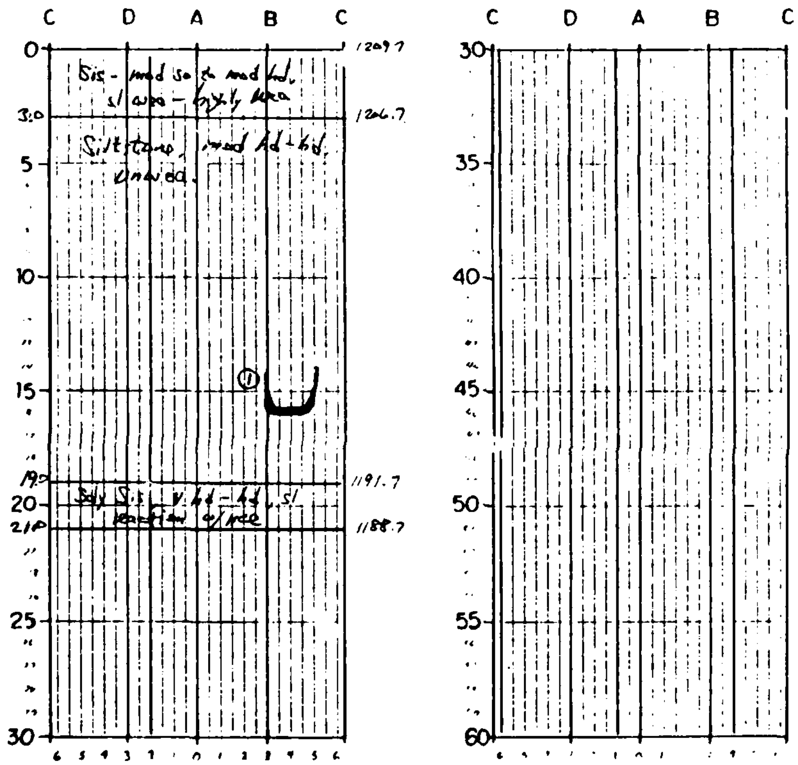
Caisson No.: CA 1-2

Surface El: 1209.7

El TOR: 1209.7

BH 1188.7





A 5 ft deep jackhammer "post tar hole" was drilled below bottom of caisson from 21.0 to 26.0 ft. w/ hard unweathered rock for full depth.
At 21 ft the cutting rate was 1"/5 hrs w/ approx 100 carbide picks worn out

REMARKS: Hole was terminated at 21.0

FEATURE NO.	DESCRIPTION
1	Jt, Ti, clean, mod rough, long dip N-ea, ≈ vert.

Line A-C is along caisson row alignment.
Bearing: N43W

Groundwater: None

Drill Time:

Concrete Placed: 7-9-91

Plate H-6

Hole No. CA 1-3

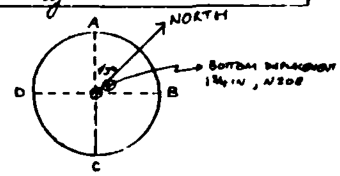
DRILLING LOG	DIVISION: ORD	INSTALLATION: NED	SHEET 1 of 1 SHEETS
1. PROJECT: HARLAN DIVERSION PROJECT		10. SIZE AND TYPE OF BIT: 48 in Rock Auger / Coring Tool	
2. LOCATION (Coordinates or Station): Highway 38 Bridge Abutment No.		11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL	
3. DRILLING AGENCY: Hayes		12. MANUFACTURER'S DESIGNATION OF DRILL: Hughes LDH 70	
4. HOLE NO. (As shown on drawing title and file number): A 1-3		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED — / UNDISTURBED —	
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES: —	
6. DIRECTION OF HOLE: [X] VERTICAL [ ] INCLINED ___ DEG. FROM VERT.		15. ELEVATION GROUND WATER: NONE	
		16. DATE HOLE: STARTED 6/27/91 / COMPLETED 7/1/91	
7. THICKNESS OF OVERBURDEN: 7.0 FT		17. ELEVATION TOP OF HOLE: 1209.7	
8. DEPTH DRILLED INTO ROCK: 28.5 FT		18. TOTAL CORE RECOVERY FOR BORING: —	
9. TOTAL DEPTH OF HOLE: 35.5 FT		19. SIGNATURE OF INSPECTOR: Tim Sky	

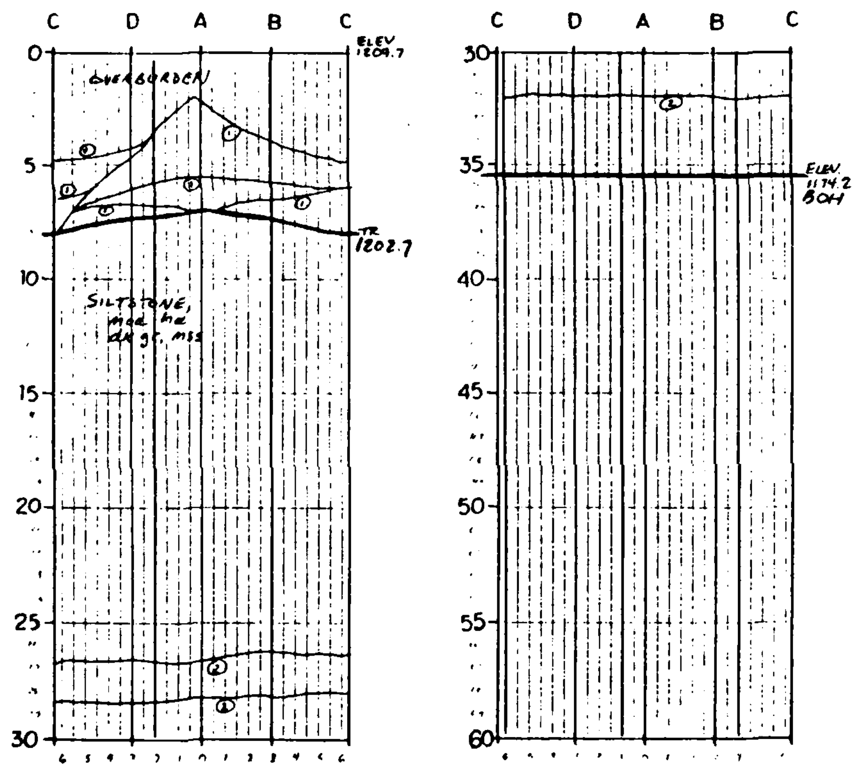
Caisson No.: CA1-3

Surface El: 1209.7

El TOR: 1202.7

BH 1174.2





FEATURE NO.	DESCRIPTION
1	Slip surface in overburden
2	Bedding plane, B4, H4, sis, c gra, 1 97, Near horizontal

REMARKS:

Line A-C is along caisson row alignment.
Bearing: N43W

Groundwater: NONE

Drill Time:

Concrete Placed: 7-1-91

Plate H-7

Hole No. 1-4

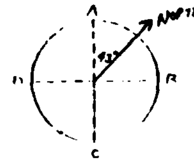
DRILLING LOG	DIVISION ORD
INSTALLATION ORD	SHEET 1 of 1 SHEETS
1. PROJECT HARLAN DIVERSION PROJECT	10. SIZE AND TYPE OF BIT 48 in AUGER/CORING TOOL
2. LOCATION (Coordinates or Station) Highway 38 Bridge Abutment No. 1	11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL
3. DRILLING AGENCY Hayes	12. MANUFACTURER'S DESIGNATION OF DRILL HUGHES LDH-70
4. HOLE NO. (As shown on drawing title and file number) A 1-4	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED — UNDISTURBED —
5. NAME OF DRILLER JERRY HAYES	14. TOTAL NUMBER CORE BOXES —
6. DIRECTION OF HOLE [x] VERTICAL [ ] INCLINED DEG. FROM VERT.	15. ELEVATION GROUND WATER 1167.0
7. THICKNESS OF OVERBURDEN 18.0 FT	16. DATE HOLE: STARTED — COMPLETED 7/15/91
8. DEPTH DRILLED INTO ROCK 29.3 FT	17. ELEVATION TOP OF HOLE 1209.7
9. TOTAL DEPTH OF HOLE 47.3 FT	18. TOTAL CORE RECOVERY FOR BORING —
	19. SIGNATURE OF INSPECTOR Tim Sly

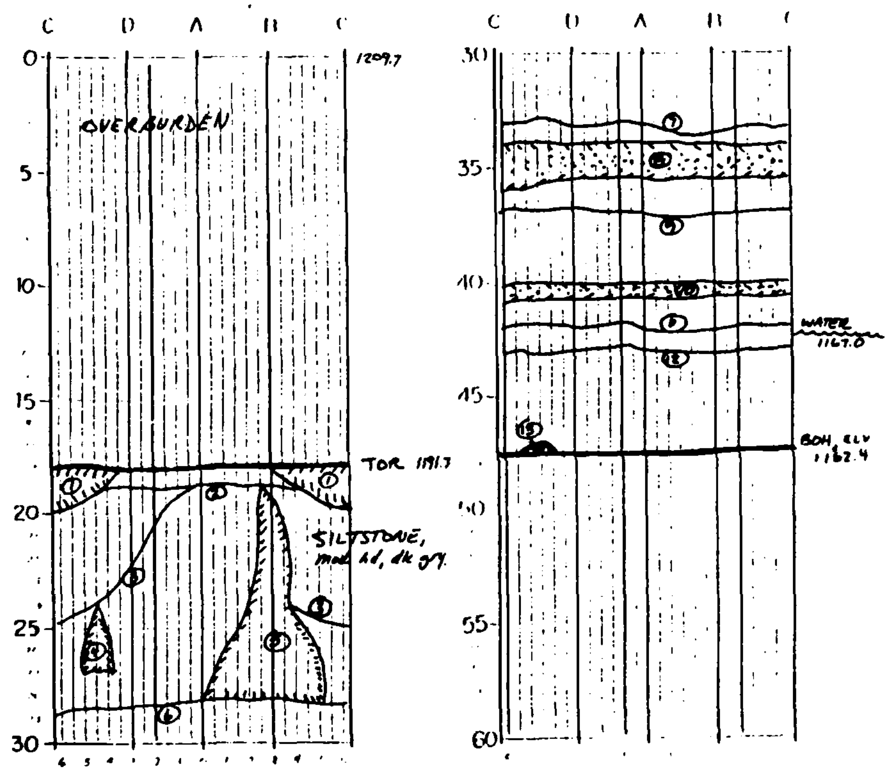
Caisson No.: CA 1-4

Surface El: 1209.7

El TOR: 1191.7

BH 1162.4





FEATURE NO.	DESCRIPTION
1	Cly lens, H2, W4
2 6 7 9 11 12	Bdg plns, 0°, T2, M2
3	Jt, N80E, 75 SE, C3, 0°, T5, R2, H4, M4
4 5	Joint Filling, cly, H1, W5
8 10	sh?, c gm, H4, W1
13	cly lens, H2, W4, flowing water (1 gpm).

REMARKS:

Line A-C is along caisson row alignment.
Bearing: N 43° W

Groundwater: Flowing at 1162.5 Standing at 1167.0

Drill Time:

Concrete Placed: 7/18/91

Plate E 8

DRILLING LOG	DIVISION ORD	INSTALLATION HED	SHEET 1 of 1 sheets

1. PROJECT: HARLAN DIVERSION PROJECT
2. LOCATION (Coordinates or Station): Highway 38 Bridge Abutment No. 1
3. DRILLING AGENCY: Hayes
4. HOLE NO. (As shown on drawing title and file number): A 1-5
5. NAME OF DRILLER: JERRY HAYES
6. DIRECTION OF HOLE: [x] VERTICAL [ ] INCLINED ___ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: 22.5
8. DEPTH DRILLED INTO ROCK: 24.3
9. TOTAL DEPTH OF HOLE: 46.8

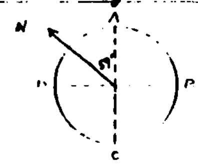
10. SIZE AND TYPE OF BIT: 4 ft AUGER/CORING TOOL
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: HUGHES LDH-70
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED – UNDISTURBED –
14. TOTAL NUMBER CORE BOXES: –
15. ELEVATION GROUND WATER: ND
16. DATE HOLE: STARTED — COMPLETED 7/29/91
17. ELEVATION TOP OF HOLE: 1210.2
18. TOTAL CORE RECOVERY FOR BORING: –
19. SIGNATURE OF INSPECTOR: Tim Sky

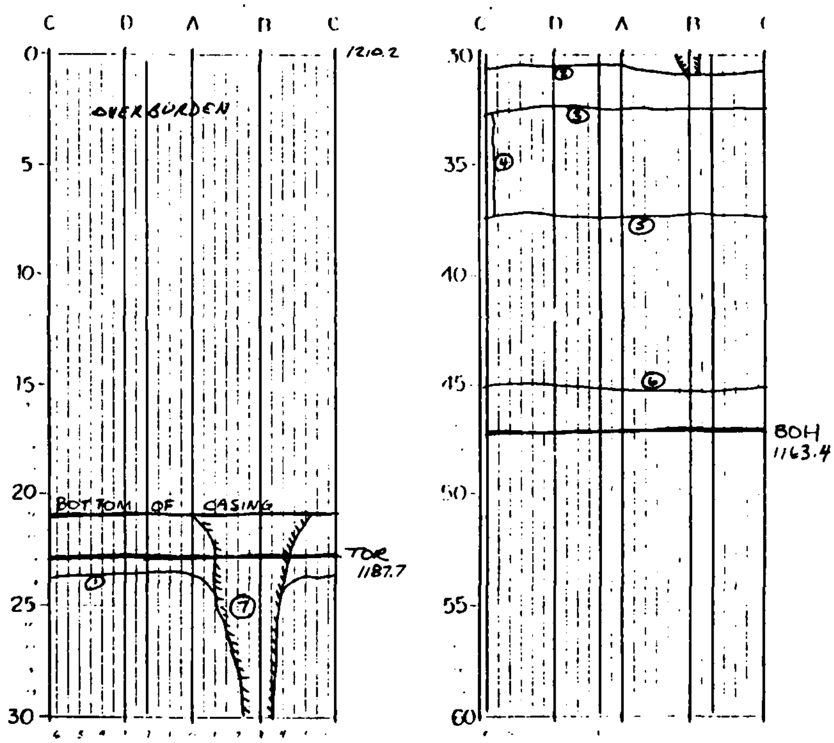
Caisson No.: A1-5

Surface El: 1210.2

El TOR: 1187.7

BH 1163.4





FEATURE NO.	DESCRIPTION
1,2,3,5,6	Bedding Planes, B4, Silt, cgm, lg19, W6, H4, Horizontal
4	Fracture, C2, O3, T3, R4, N80E, vertical
7	Fracture, C3, O8, T5, R2, HL4, M4 cly filling H1, W5. N75W, 70 NE

REMARKS:

Line A-C is along caisson row alignment.
Bearing: N59°E

Groundwater: ND

Drill Time:

Concrete Placed: 7-30-91

Sheet 1 of 1

DRILLING LOG	DIVISION ORD	INSTALLATION HED	SHEET 1 OF 1 SHEETS

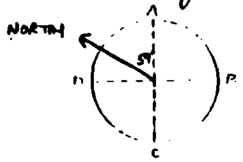
1. PROJECT: HARLAN DIVERSION PROJECT
2. LOCATION: Highway 38 Bridge Abutment No.
3. DRILLING AGENCY: Hayes
4. HOLE NO.: A 1-7
5. NAME OF DRILLER: JERRY HAYES
6. DIRECTION OF HOLE: [x] VERTICAL [ ] INCLINED
7. THICKNESS OF OVERBURDEN: 18.2
8. DEPTH DRILLED INTO ROCK: 18.9
9. TOTAL DEPTH OF HOLE: 37.1
10. SIZE AND TYPE OF BIT: 48 in ROCK AUGER
11. DATUM FOR ELEVATION SHOWN: MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: HUGHES LDH-70
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED — UNDISTURBED —
14. TOTAL NUMBER CORE BOXES: —
15. ELEVATION GROUND WATER: ND
16. DATE HOLE: STARTED 7/16/91 COMPLETED 7/17/91
17. ELEVATION TOP OF HOLE: 1209.6
18. TOTAL CORE RECOVERY FOR BORING: —
19. SIGNATURE OF INSPECTOR: Tom Sly

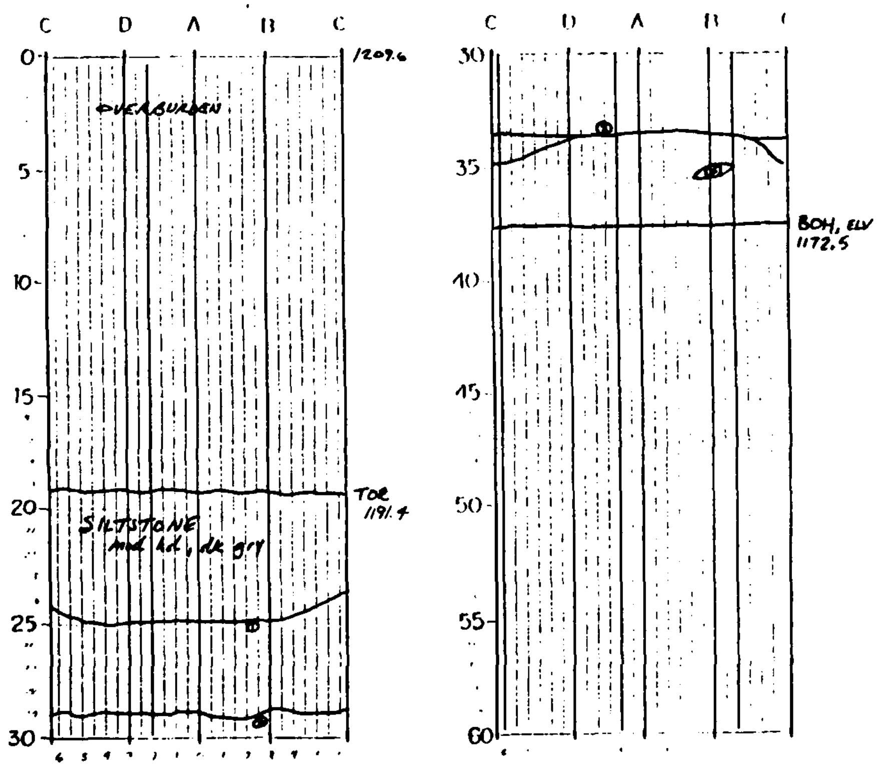
Caisson No.: CA1-7

Surface El: 1209.6

El TOR: 1191.4

BH 1172.5





FEATURE NO.	DESCRIPTION
1,2,3	Bedding planes, OB, T2, M2
4	Cly lens, N2, W4

REMARKS:

Line A-C is along caisson row alignment.
Bearing: N 59° E

Groundwater: 0.5 ft STANDING

Drill Time:

Concrete Placed: 7/18/91

Plate H-10

Hole No. CA 1-8

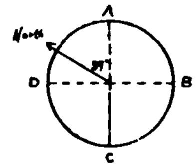
DRILLING LOG	DIVISION ORD	INSTALLATION NED	SHEET 1 OF 1 SHEETS
1. PROJECT HARLAN DIVERSION PROJECT		10. SIZE AND TYPE OF BIT 48 in Rock Auger	
2. LOCATION (Coordinates or Station) Highway 38 Bridge Abutment No. 1		11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL	
3. DRILLING AGENCY Hayes		12. MANUFACTURER'S DESIGNATION OF DRILL Hughes LDH-70	
4. HOLE NO. (As shown on drawing title and file number)	A 1-8	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED – / UNDISTURBED –
5. NAME OF DRILLER Jerry Hayes		14. TOTAL NUMBER CORE BOXES –	
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.		15. ELEVATION GROUND WATER NONE	
		16. DATE HOLE	STARTED 7/01/91 / COMPLETED 7/03/91
7. THICKNESS OF OVERBURDEN	20.5	17. ELEVATION TOP OF HOLE 1209.7	
8. DEPTH DRILLED INTO ROCK	15.0	18. TOTAL CORE RECOVERY FOR BORING –	
9. TOTAL DEPTH OF HOLE	35.5	19. SIGNATURE OF INSPECTOR [signature]	

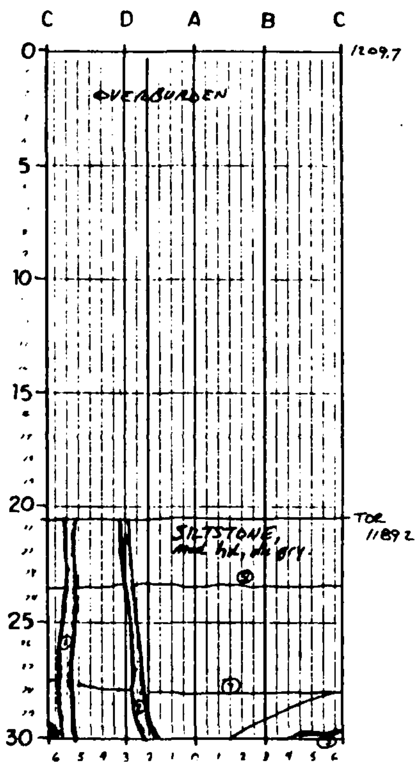
Caisson No.: CA-1-8

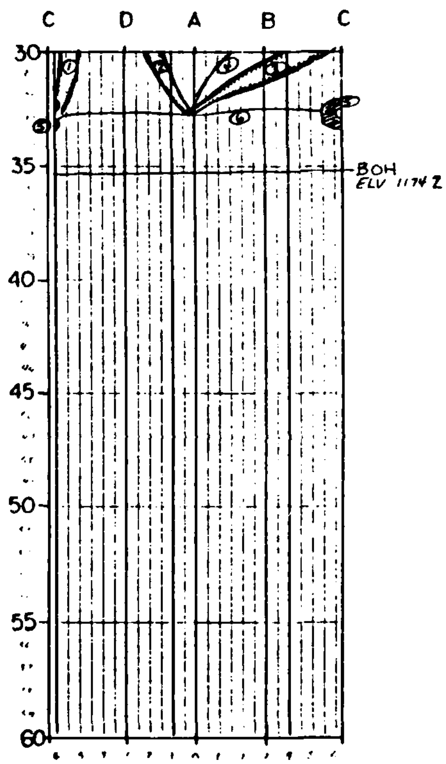
Surface El: 1209.7

El TOR: 1189.2

BH 1174.2







FEATURE NO.	DESCRIPTION
1, 2	Joint, C3, OB, T5, R5, HL4, M4, {N 20°W / Vertical
3	Cly lens, H2, W4
4	Frac, C2, OB, T4, R4, HL4, M2, {N 20°E / 45° NW
5	Cly lens, H2, W4
6, 7, 8	Bedding planes, OB, T2, M2

REMARKS:

Line A-C is along caisson row alignment.
Bearing: N 59° E

Groundwater: NONE

Drill Time: ____________

Concrete Placed: 7-3-91

Hole No. 2-1

DRILLING LOG	DIVISION ORD	INSTALLATION NED	SHEET 1 of 1 SHEETS

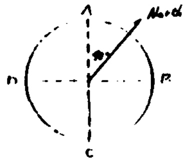
1. PROJECT	HARLAN DIVERSION PROJECT	10. SIZE AND TYPE OF BIT	4 FT Ø AUGER/CORING TOOL
2. LOCATION (Coordinates or Station)	Highway 38 Bridge Abutment No. 2	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	MSL
3. DRILLING AGENCY	Hayes	12. MANUFACTURER'S DESIGNATION OF DRILL	HUGHES LDH-70
4. HOLE NO. (As shown on drawing title and file number)	A 2-1	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED – UNDISTURBED –
5. NAME OF DRILLER	JERRY HAYES	14. TOTAL NUMBER CORE BOXES	–
6. DIRECTION OF HOLE	[x] VERTICAL [ ] INCLINED ___ DEG. FROM VERT.	15. ELEVATION GROUND WATER	ND
		16. DATE HOLE	STARTED ___ COMPLETED 7/25/91
7. THICKNESS OF OVERBURDEN	0.0	17. ELEVATION TOP OF HOLE	1211.8
8. DEPTH DRILLED INTO ROCK	22.6	18. TOTAL CORE RECOVERY FOR BORING	–
9. TOTAL DEPTH OF HOLE	22.6	19. SIGNATURE OF INSPECTOR	Tim Sky

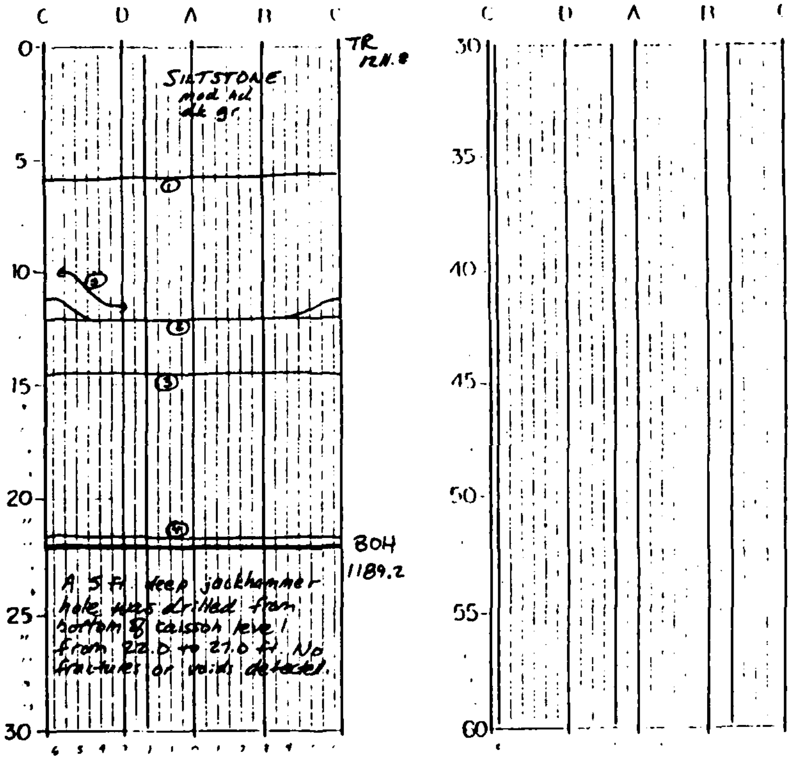
Caisson No.: CA2-1

Surface El: 1211.8

El TOR: 1211.8

BH 1189.2





FEATURE NO.	DESCRIPTION
1,2,3	Bedding plane, Sist, B3, Cgrn, Igr, horizontal, W1, H4
5	Fracture, C1, O6, T1, R4, HL4, M2

REMARKS:

Line A-C is along caisson row alignment.
Bearing: N43W

Groundwater: NONE

Drill Time:

Concrete Placed: 7-31-91

Plate H-12

Hole No. CA 2-2

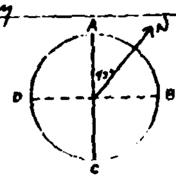
DRILLING LOG	DIVISION ORD	INSTALLATION NED	SHEET 1 OF 1 SHEETS
1. PROJECT: HARLAN DIVERSION PROJECT		10. SIZE AND TYPE OF BIT: 60 in. Rock Auger	
2. LOCATION (Coordinates or Station): Highway 38 Bridge Abutment No. 2		11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL	
3. DRILLING AGENCY: Hayes		12. MANUFACTURER'S DESIGNATION OF DRILL: HUGHES LDH-70	
4. HOLE NO. (As shown on drawing title and file number): A 2-2		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED — UNDISTURBED —	
5. NAME OF DRILLER: SHERMAN		14. TOTAL NUMBER CORE BOXES: —	
6. DIRECTION OF HOLE: [x] VERTICAL [ ] INCLINED ___ DEG. FROM VERT.		15. ELEVATION GROUND WATER: 1178.6 STANDING	
7. THICKNESS OF OVERBURDEN: 4.6		16. DATE HOLE: STARTED / COMPLETED	
8. DEPTH DRILLED INTO ROCK: 29.6		17. ELEVATION TOP OF HOLE: 1211.8	
9. TOTAL DEPTH OF HOLE: 34.2		18. TOTAL CORE RECOVERY FOR BORING: —	
		19. SIGNATURE OF INSPECTOR: Tim Sky	

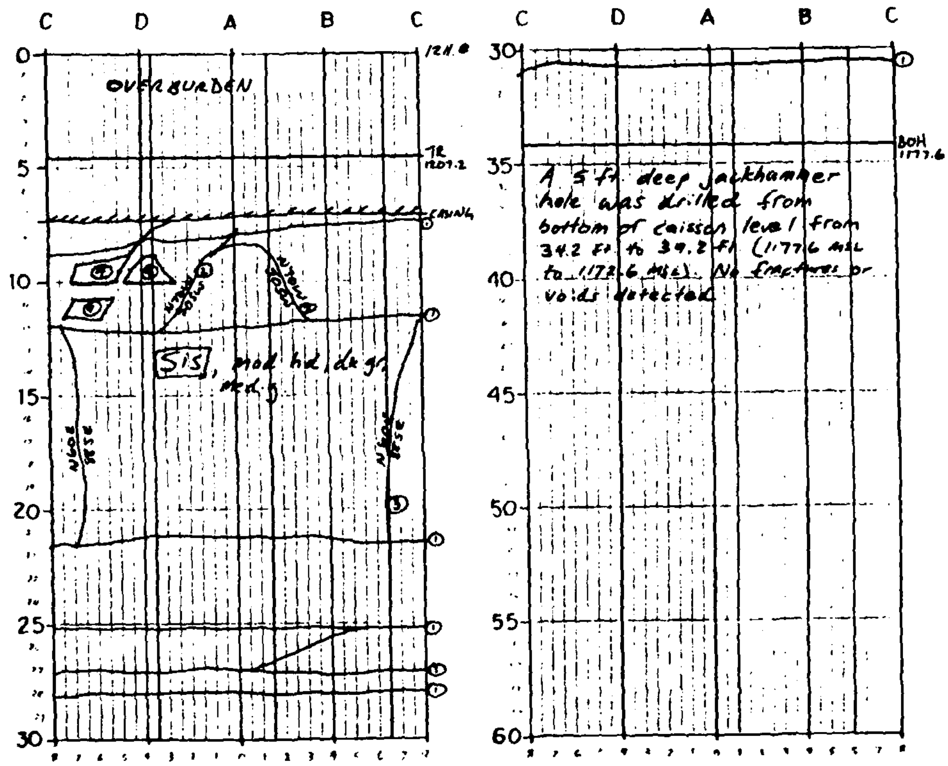
Caisson No.: CA2-2

Surface El: 1211.8

El TOR: 1207.2

BH 1177.6





FEATURE NO.	DESCRIPTION
1	Bedding plane, 1 gr, B4, H4, W2, near horizontal
2	Fracture, C2, O2, T4, R2, HL4, H4, N70W, 50SW
3	Fracture, C2, O2, T4, R2, HL4, H4, N60E, 80SE
4	Spalls to N45E, vertical face

REMARKS:

Line A-C is along caisson row alignment.
Bearing: N 43° W

Groundwater: 1178.6 STANDING NO FLOW.

Drill Time: ________

Concrete Placed: ________

Hole No. A 2-3

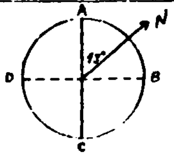
DRILLING LOG	DIVISION ORD	INSTALLATION NED	SHEET 1 OF 1 SHEETS
1. PROJECT HARLAN DIVERSION PROJECT		10. SIZE AND TYPE OF BIT	
2. LOCATION (Coordinates or Station) Highway 38 Bridge Abutment No. 2		11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL	
3. DRILLING AGENCY Hayes		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number)	A 2-3	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED — UNDISTURBED —
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	—
6. DIRECTION OF HOLE [x] VERTICAL [ ] INCLINED DEG. FROM VERT.		15. ELEVATION GROUND WATER	1184.7 FLOWING
		16. DATE HOLE	STARTED — COMPLETED 7/24/91
7. THICKNESS OF OVERBURDEN	9.0	17. ELEVATION TOP OF HOLE	1211.2
8. DEPTH DRILLED INTO ROCK	31.1	18. TOTAL CORE RECOVERY FOR BORING	
9. TOTAL DEPTH OF HOLE	40.1	19. SIGNATURE OF INSPECTOR	

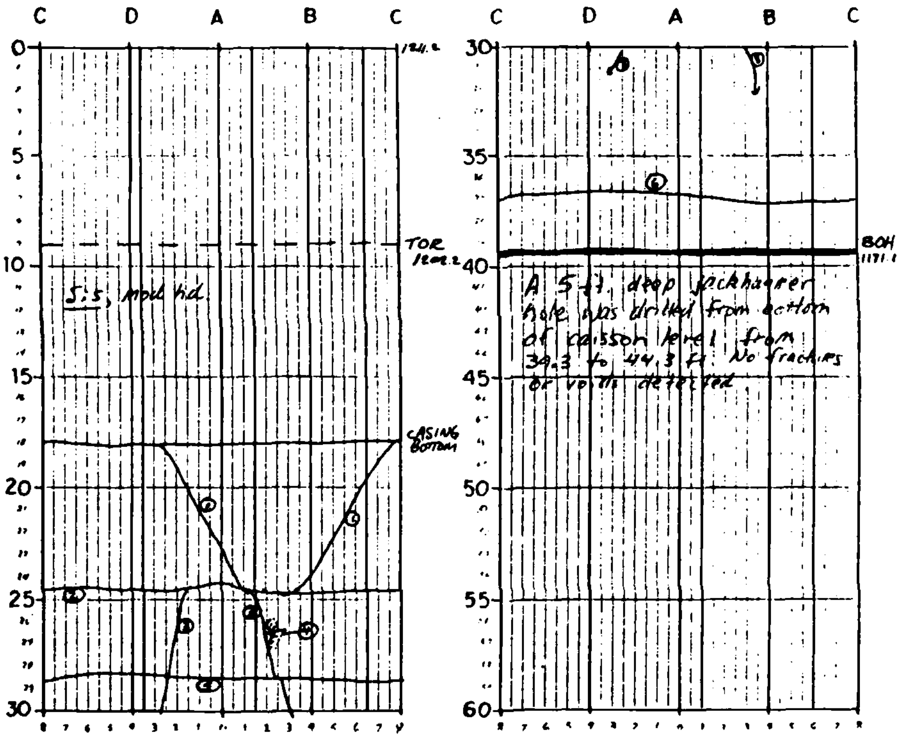
Caisson No.: CA 2-3

Surface El: 1211.2

El TOR: 1202.2

BH 1171.1





FEATURE NO.	DESCRIPTION
①	JOINT, N40W 70°NE, C2, O3, T4, R1, MLH, MS
②⑤⑥	BEDDING PLANE, NEAR HORIZONTAL, B4 SIST, LGRY, C GRN, GLASS ABOVE PLANE
③	JOINT, N50E, 85°NW, C2, O3, T4, R1, MLH MG (see ⑤ below)
④	WATER FLOW POINT – 12 gal/min.

REMARKS:

Line A-C is along caisson row alignment.
Bearing: N43W

Groundwater: 1184.7 FLOWING

Drill Time:

Concrete Placed: 7-30-91

A 2-4

DRILLING LOG	DIVISION ORD	INSTALLATION HED	SHEET 1 OF 1 SHEETS

1. PROJECT: HARLAN DIVERSION PROJECT
2. LOCATION (Coordinates or Station): Highway 38 Bridge Abutment No.
3. DRILLING AGENCY: Hayes
4. HOLE NO. (As shown on drawing title and file number): A2-4
5. NAME OF DRILLER:
6. DIRECTION OF HOLE: [x] VERTICAL [ ] INCLINED ___ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: 17.1
8. DEPTH DRILLED INTO ROCK: 25.0
9. TOTAL DEPTH OF HOLE: 42.1

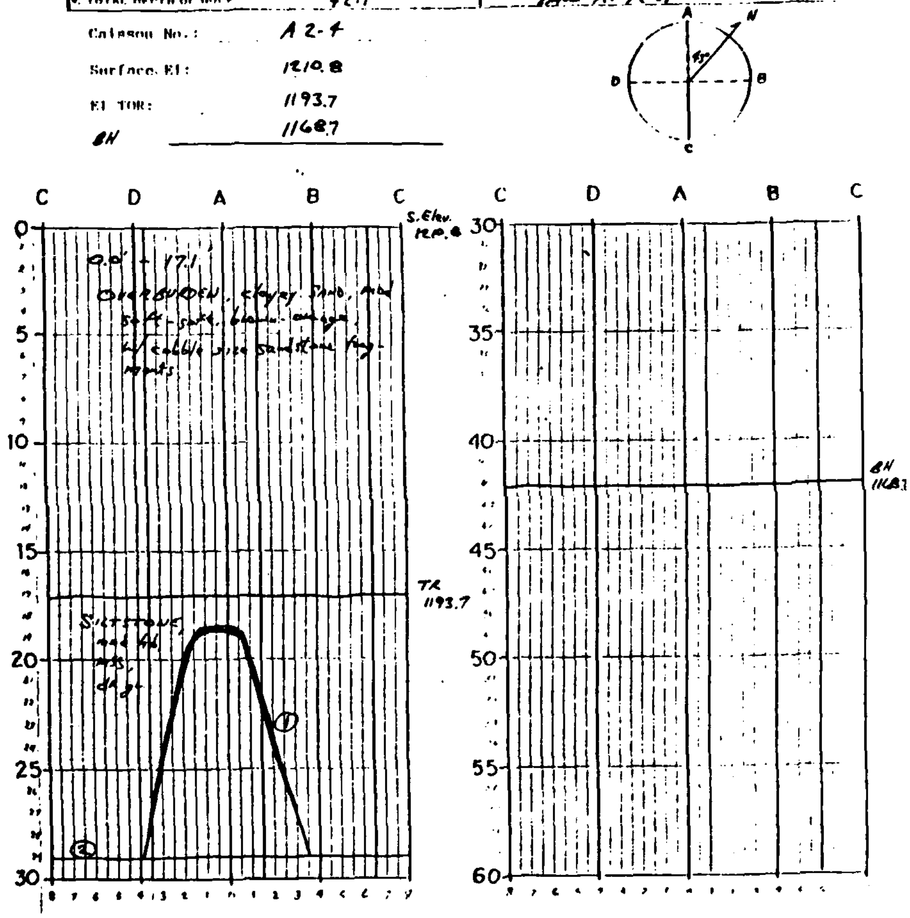
10. SIZE AND TYPE OF BIT: 60" Rock Auger
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: HUGHES LDH-70
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED — UNDISTURBED —
14. TOTAL NUMBER CORE BOXES: —
15. ELEVATION GROUND WATER: 1170.7
16. DATE HOLE: STARTED COMPLETED
17. ELEVATION TOP OF HOLE: 1210.8
18. TOTAL CORE RECOVERY FOR BORING: —
19. SIGNATURE OF INSPECTOR: Paul A. Ross

Caisson No.: A 2-4

Surface El: 1210.8

El TOR: 1193.7

BH: 1168.7



FEATURE NO.	DESCRIPTION
1	Joint N60E, 65 SE OP, T 3-5 (up to 0.6 ft. so clay + sils frags), RS, HL4, MS
2	Bdd pln, OP, T4, RS, HL4, M2, ~ hor

REMARKS:

Line A-C is along caisson row alignment.
Bearing: N43W

Groundwater: 1170.7

Drill Time: ______

Concrete Placed: ______

Hole No. CA 2 - 5

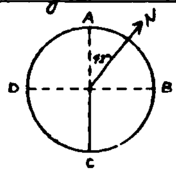
DRILLING LOG	DIVISION ORD	INSTALLATION NED	SHEET 1 OF 1 SHEETS
1. PROJECT: HARLAN DIVERSION PROJECT		10. SIZE AND TYPE OF BIT	
2. LOCATION (Coordinates or Station): Highway 38 Bridge Abutment No. ____		11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL	
3. DRILLING AGENCY: Hayes		12. MANUFACTURER'S DESIGNATION OF DRILL: HUGHES LDH-70	
4. HOLE NO. (As shown on drawing title and file number): A 2-5		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED — / UNDISTURBED —	
5. NAME OF DRILLER: SHERMAN		14. TOTAL NUMBER CORE BOXES: —	
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.		15. ELEVATION GROUND WATER: NONE	
		16. DATE HOLE: STARTED / COMPLETED	
7. THICKNESS OF OVERBURDEN: 18.0		17. ELEVATION TOP OF HOLE: 1211.0	
8. DEPTH DRILLED INTO ROCK: 17.9		18. TOTAL CORE RECOVERY FOR BORING: — %	
9. TOTAL DEPTH OF HOLE: 35.9		19. SIGNATURE OF INSPECTOR: Tim Sky	

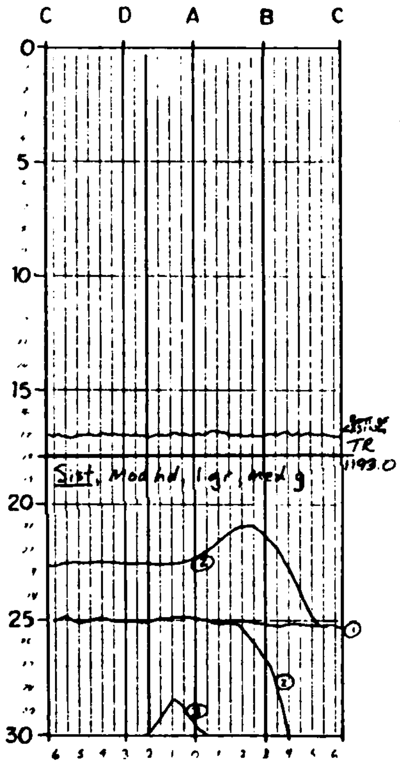
Caisson No.: CA2-5

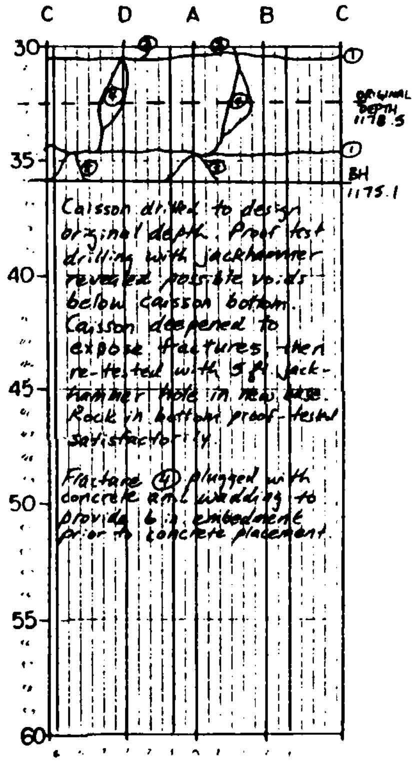
Surface El: 1211.0

El TOR: 1193.0

BH 1175.1







FEATURE NO.	DESCRIPTION
1	Bedding planes, B4, lgr
2	Fractures, C2, O8, T3, R4, HL4, M2, N60W, 75SW
3	Joint face, N10W, 72 SW.
4	Fracture, C2, O5(1.6 ft), HL4, T8, R2, M2, N20E, 80NW.
5	Fracture, C2, O8, T5, R4, HL4, M4, N25E, 75 NW.

REMARKS:

Line A-C is along caisson row alignment.
Bearing: N43°W

Groundwater: NONE

Drill Time: ____

Concrete Placed: ____

A2-6

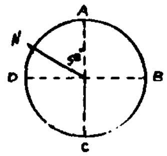
DRILLING LOG	DIVISION ORD	INSTALLATION NED	SHEET 1 OF 1 SHEETS
1. PROJECT: HARLAN DIVERSION PROJECT		10. SIZE AND TYPE OF BIT: 48 " Rock Auger	
2. LOCATION (Coordinates or Station): Highway 38 Bridge Abutment No. 2		11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL	
3. DRILLING AGENCY: Hayes		12. MANUFACTURER'S DESIGNATION OF DRILL: Hughes LDH-70	
4. HOLE NO. (As shown on drawing title and file number): CK A2-6		13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED — UNDISTURBED —	
5. NAME OF DRILLER:		14. TOTAL NUMBER CORE BOXES: —	
6. DIRECTION OF HOLE: [x] VERTICAL [ ] INCLINED ___ DEG. FROM VERT.		15. ELEVATION GROUND WATER: —	
		16. DATE HOLE: STARTED ___ COMPLETED 9-11-91	
7. THICKNESS OF OVERBURDEN: 14.8		17. ELEVATION TOP OF HOLE: 1211.07	
8. DEPTH DRILLED INTO ROCK: 15.5		18. TOTAL CORE RECOVERY FOR BORING: — %	
9. TOTAL DEPTH OF HOLE: 30.3		19. SIGNATURE OF INSPECTOR: [signature]	

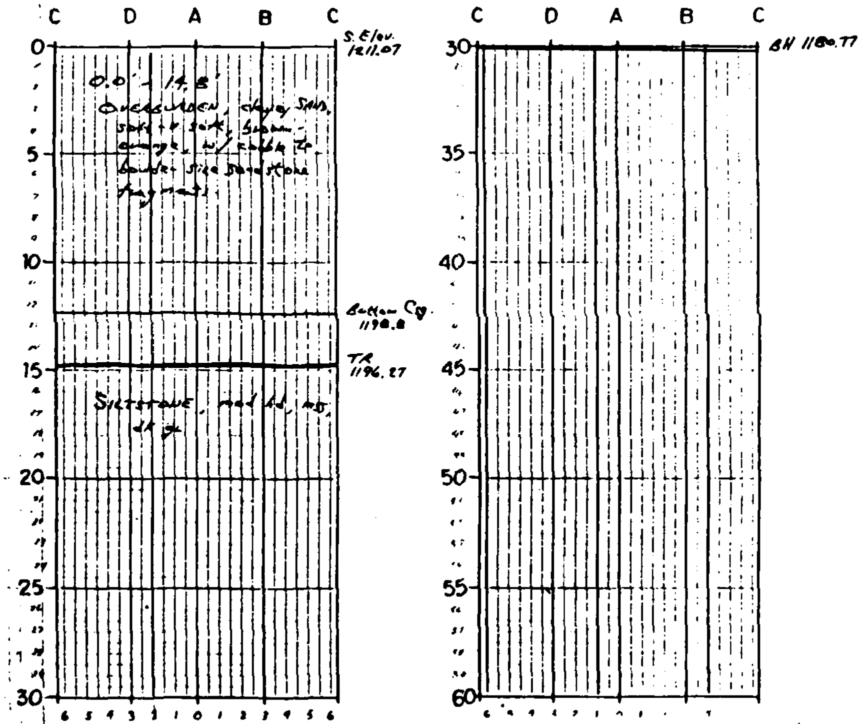
Caisson No.: A2-6

Surface El: 1211.07

El TOR: 1196.27

BH 1180.77





Note: Top of rock was erroneously called at 1199.55 when auger hit sandstone fragments, and drilling was stopped at elev 1181.27. Downhole inspection revealed TR to be lower than called. Hole was deepened to provide minimum 15 ft rock embedment.

FEATURE NO.	DESCRIPTION

REMARKS:

Line A-C is along caisson row alignment.
Bearing: N58E

Groundwater: ______

Drill Time: ______

Concrete Placed: ______

(2)

Hole No. A 2-7

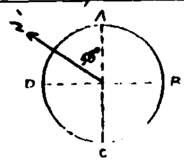
DRILLING LOG	DIVISION ORD	INSTALLATION HED	SHEET 1 OF 1 SHEETS
1. PROJECT HARLAN DIVERSION PROJECT		10. SIZE AND TYPE OF BIT	
2. LOCATION (Coordinates or Station) Highway 38 Bridge Abutment No. 2		11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL	
3. DRILLING AGENCY Hayes		12. MANUFACTURER'S DESIGNATION OF DRILL HUGHES LDH-70	
4. HOLE NO. (As shown on drawing title and file number) A 2-7		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED — UNDISTURBED —
5. NAME OF DRILLER SHERMAN		14. TOTAL NUMBER CORE BOXES —	
6. DIRECTION OF HOLE [X] VERTICAL [ ] INCLINED ___ DEG. FROM VERT.		15. ELEVATION GROUND WATER NONE	
		16. DATE HOLE	STARTED / COMPLETED
		17. ELEVATION TOP OF HOLE 1211.1	
7. THICKNESS OF OVERBURDEN 7.7		18. TOTAL CORE RECOVERY FOR BORING —	
8. DEPTH DRILLED INTO ROCK 17.8		19. SIGNATURE OF INSPECTOR Tom Sky	
9. TOTAL DEPTH OF HOLE 25.5			

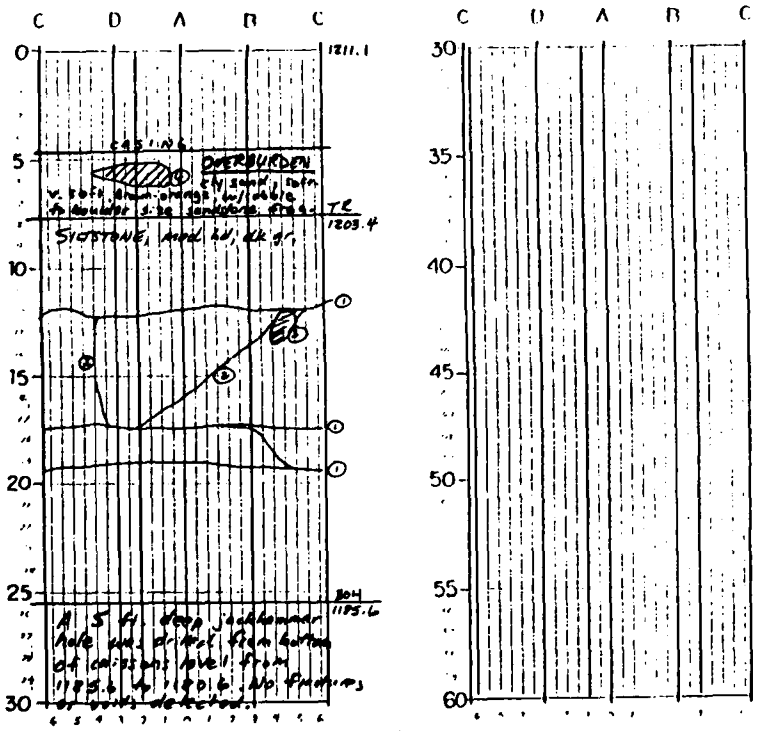
Caisson No.: A2-7

Surface El: 1211.1

El TOR: 1203.4

BoH 1185.6





FEATURE NO.	DESCRIPTION
1	Bedding planes, 84, 1 gr.
2	Fracture, C8, D6, T3, R4, NL4, M3, N95W, 80NE
3	Earth fill, wet, cly
4	ss boulder in overburden.

REMARKS:

Line A-C is along caisson row alignment.
Bearing: N58E

Groundwater: NONE

Drill Time:

Concrete Placed:

Z-8

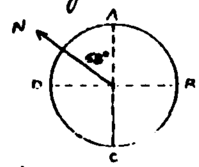
DRILLING LOG	DIVISION ORD	INSTALLATION NED	SHEET 1 OF 1 SHEETS
1. PROJECT	HARLAN DIVERSION PROJECT	10. SIZE AND TYPE OF BIT	
2. LOCATION (Coordinates or Station)	Highway 38 Bridge Abutment No.	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	MSL
3. DRILLING AGENCY	Hayes	12. MANUFACTURER'S DESIGNATION OF DRILL	HUGHES LDH 70
4. HOLE NO. (As shown on drawing title and file number)	A 2-8	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED – UNDISTURBED –
5. NAME OF DRILLER	SHERMAN	14. TOTAL NUMBER CORE BOXES	–
6. DIRECTION OF HOLE	[x] VERTICAL [ ] INCLINED ___ DEG. FROM VERT.	15. ELEVATION GROUND WATER	NONE
7. THICKNESS OF OVERBURDEN	11.5	16. DATE HOLE	STARTED – COMPLETED
8. DEPTH DRILLED INTO ROCK	16.0	17. ELEVATION TOP OF HOLE	1212.5
9. TOTAL DEPTH OF HOLE	27.5	18. TOTAL CORE RECOVERY FOR BORING	–
		19. SIGNATURE OF INSPECTOR	Tom Shy

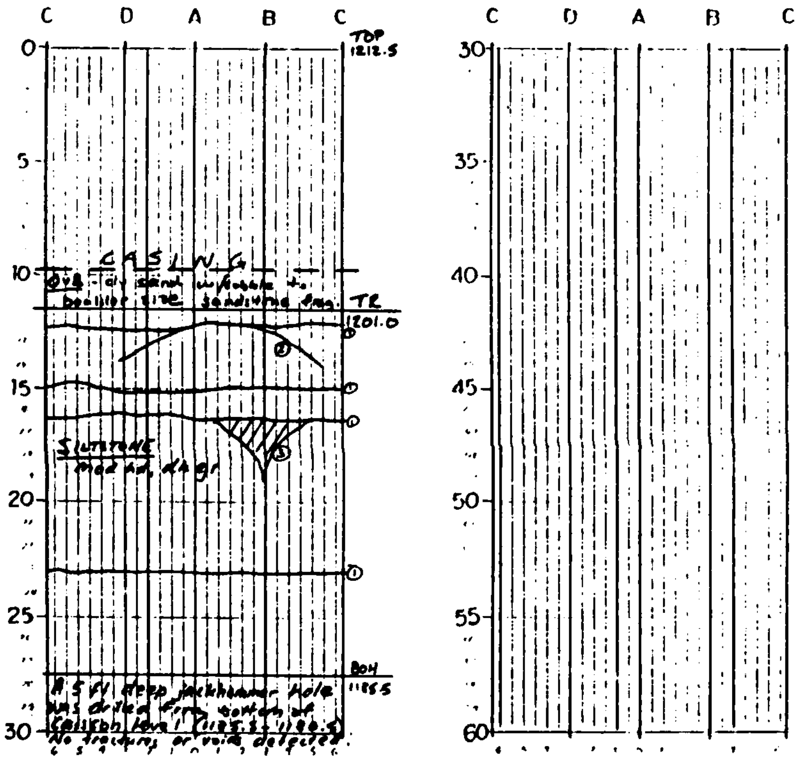
Caisson No.: A2-8

Surface El: 1212.5

El TOR: 1201.0

BOH 1185.5





FEATURE NO.	DESCRIPTION
1	Bedding planes, B4, 1 gr, near horizontal
2	Fracture, N5W, 80SW, C2, O8, T3, R4, H4, M2
3	Cly lens, O8, W4, H4

REMARKS:

Line A-C is along caisson row alignment.
Bearing: N58E

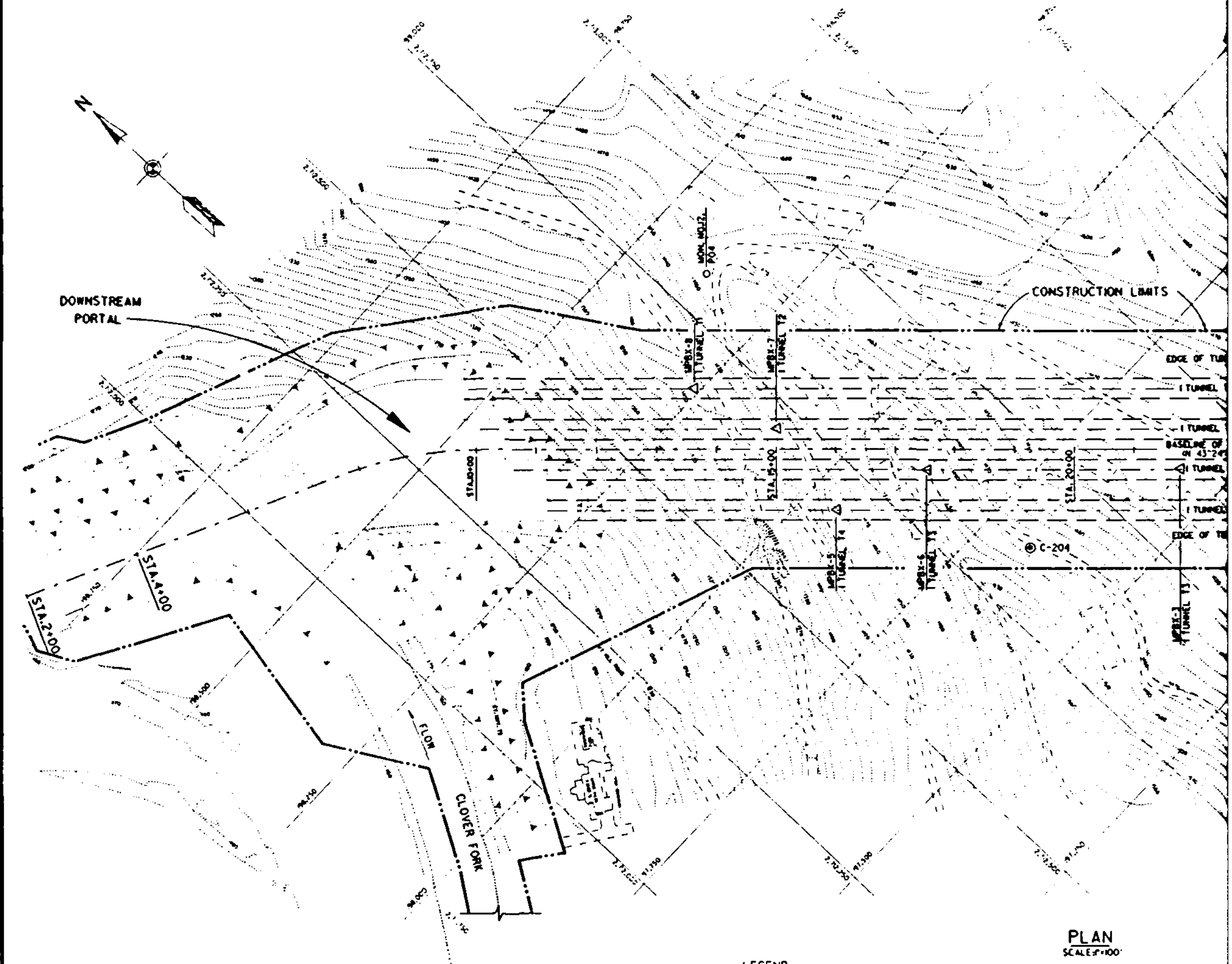
Groundwater: NONE

Drill Time: ____

Concrete Placed: ____

Appendix I - Instrumentation

Plate No.	Drawing No.	Description
I-1	Q1A-64/79.1	Plan
I-2	Q1A-64/80.3	Section and Details
I-3 thru 11	-----	Locations
I-12 thru 23	----	MPBX's
I-23	---------	Observation Well
I 24 thru 31	----	Load Cells
I 32 thru 40	----	Tape Extensometers
I 41 thru 48	----	SPBX's



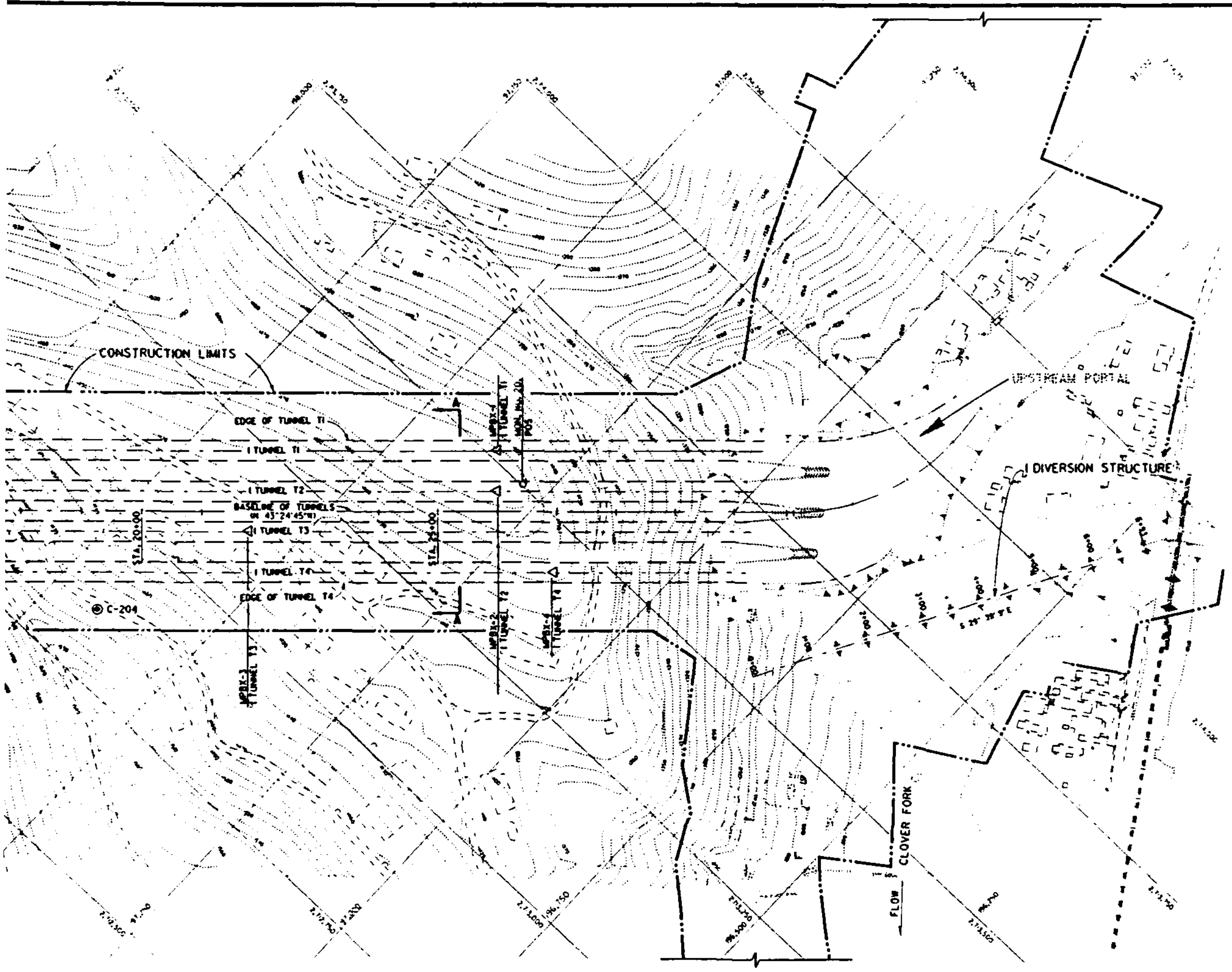
PLAN
SCALE:1"=100'

LEGEND

- ⊛ - EXISTING OBSERVATION WELL (C-204) HAVE A 3-INCH DIAMETER PVC PLASTIC RISER PIPE.
- ▽ - EXISTING (MPBX) EXTENSOMETERS (MPBX - 1 THRU MPBX-8).
- — - TAPE EXTENSOMETER (LOCATIONS NOT SHOWN).
- ○ - EXISTING MONUMENTS (MON. NO. 12, P04 & MON. NO. 20, P05).

NOTES:

1. ALL INSTRUMENTS SHALL BE INSTALLED BY THE CONTRACTOR, EXCEPT FOR THE OBSERVATION WELL AND THE (MPBX) EXTENSOMETER WHICH WERE INSTALLED BY THE GOVERNMENT.
2. ALL INSTRUMENTATION SHALL BE PROTECTED AND READ BY THE CONT THROUGHOUT THE DURATION OF THE CONTRACT. A PROTECTIVE HOUS SHALL BE PROVIDED FOR EACH INSTRUMENT.
3. SEE DWG. NO. 01A-64/80 FOR INSTRUMENTATION SECTION AND DETAILS OF INSTRUMENTS.
4. THE (MPBX) EXTENSOMETERS LOCATIONS ARE APPROXIMATE.
5. LOCATIONS OF THE (SPBX) EXTENSOMETERS, ROCK BOLT LOAD CELLS AND (Tx) TAPE EXTENSOMETERS ARE NOT SHOWN. SEE DWG. NO. 01A-64/80.
6. FINAL LOCATIONS OF INSTRUMENTS MAY BE CHANGED FROM THOSE SHOWN DUE TO GEOLOGIC CONDITIONS.



PLAN

SCALE 1"=100'

WELL (C-204) HAVE A 3-INCH
RISER PIPE.
OMETERS (MPBX - 1 THRU MPBX-8).
OCATIONS NOT SHOWN).
ION. NO. 12, P04 & MON. NO. 20, P05).

BE INSTALLED BY THE CONTRACTOR.
ATION WELL AND THE (MPBX) EXTENSOMETERS.
Y THE GOVERNMENT.

ALL BE PROTECTED AND READ BY THE CONTRACTOR
ON OF THE CONTRACT. A PROTECTIVE HOUSING
EACH INSTRUMENT.
FOR INSTRUMENTATION SECTION AND

RS LOCATIONS ARE APPROXIMATE.

EXTENSOMETERS, ROCK BOLT
PE EXTENSOMETERS ARE NOT SHOWN.

TRUMENTS MAY BE CHANGED
TO GEOLOGIC CONDITIONS.

Revisions	Date	Description	By	Checked
J	5-31-89	CONFORMING TO REVIEW COMMENTS	W.L.	C.E.D.

100' 0 100'
Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY

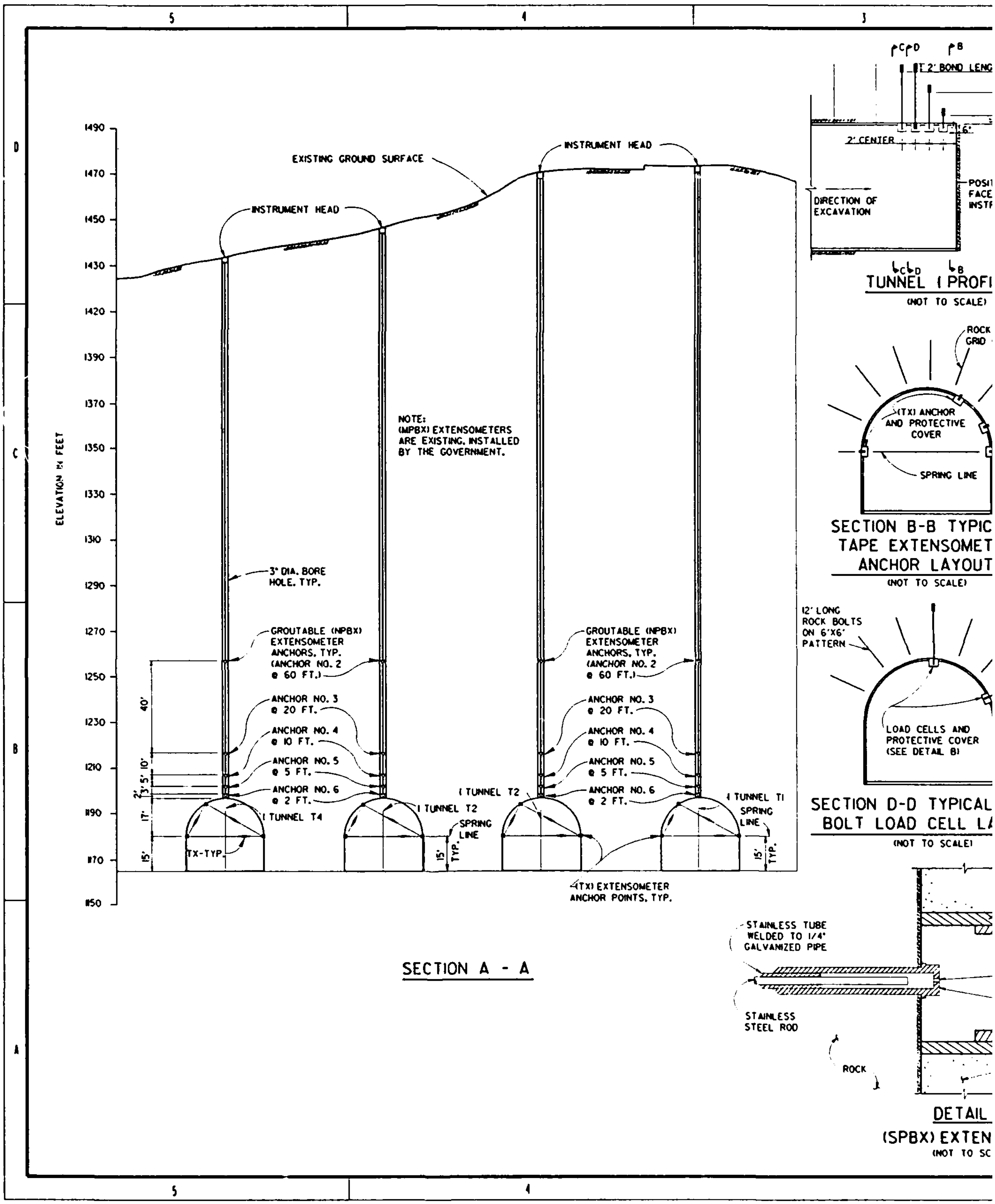
DIVERSION TUNNELS

INSTRUMENTATION PLAN

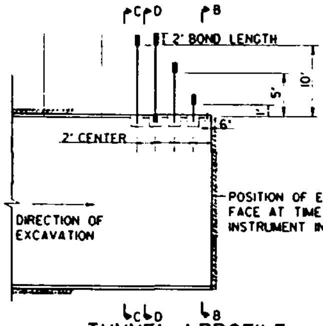
Designed By: C. E. DAVIS
Drawn By: LYLA LEAS
Checked By: Charles E. Davis

Drawing Number: OIA-64/79.1

PLATE I-1



EXISTING GROUND SURFACE
INSTRUMENT HEAD
INSTRUMENT HEAD
ELEVATION IN FEET
1490
1470
1450
1430
1420
1390
1370
1350
1330
1310
1290
1270
1250
1230
1210
1190
1170
1150
NOTE:
(MPBX) EXTENSOMETERS ARE EXISTING, INSTALLED BY THE GOVERNMENT.
3" DIA. BORE HOLE, TYP.
GROUTABLE (NPBX) EXTENSOMETER ANCHORS, TYP. (ANCHOR NO. 2 @ 60 FT.)
ANCHOR NO. 3 @ 20 FT.
ANCHOR NO. 4 @ 10 FT.
ANCHOR NO. 5 @ 5 FT.
ANCHOR NO. 6 @ 2 FT.
TUNNEL T4
TUNNEL T2
TUNNEL T1
SPRING LINE
TX-TYP.
15' TYP.
(TX) EXTENSOMETER ANCHOR POINTS, TYP.
SECTION A - A
2' BOND LENGTH
2' CENTER
DIRECTION OF EXCAVATION
TUNNEL PROFI
(NOT TO SCALE)
ROCK GRID
(TX) ANCHOR AND PROTECTIVE COVER
SPRING LINE
SECTION B-B TYPIC TAPE EXTENSOMET ANCHOR LAYOUT
(NOT TO SCALE)
12' LONG ROCK BOLTS ON 6'X6' PATTERN
LOAD CELLS AND PROTECTIVE COVER (SEE DETAIL B)
SECTION D-D TYPICAL BOLT LOAD CELL L
(NOT TO SCALE)
STAINLESS TUBE WELDED TO 1/4" GALVANIZED PIPE
STAINLESS STEEL ROD
ROCK
DETAIL
(SPBX) EXTEN
(NOT TO SC

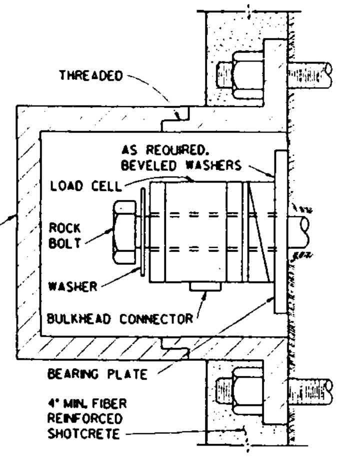


TUNNEL ℄ PROFILE

(NOT TO SCALE)

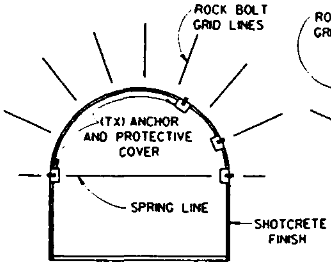
LEGEND

- SINGLE POINT BOREHOLE EXTENSOMETER (SPBX) WITH PROTECTIVE COVER
- INSTRUMENTED ROCK BOLT WITH LOAD CELL AND PROTECTIVE COVER
- (TX) TAPE EXTENSOMETER ANCHOR WITH PROTECTIVE COVER
- FULLY GROUTED PRODUCTION ROCK BOLT



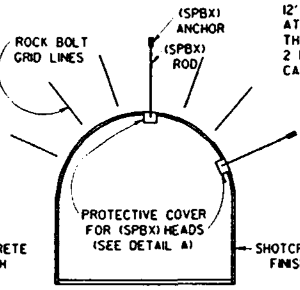
DETAIL B
ROCK BOLT LOAD CELL

(NOT TO SCALE)



SECTION B-B TYPICAL TAPE EXTENSOMETER ANCHOR LAYOUT

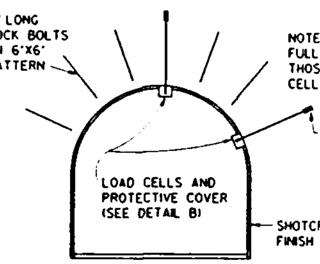
(NOT TO SCALE)



NOTE: ROCK BOLT SHALL BE 12' LONG, ANCHORED AT THE BOTTOM OF THE HOLE, WITH 2 FAST SET RESIN CARTRIDGES.

SECTION C-C TYPICAL (SPBX) LAYOUT

(NOT TO SCALE)



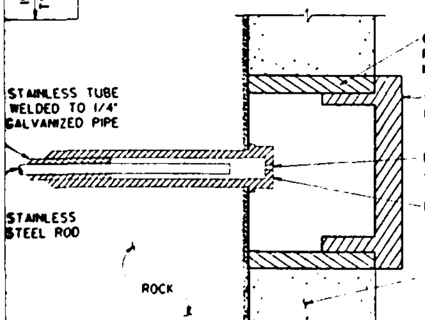
NOTE: ALL ROCK BOLTS FULLY GROUTED EXCEPT THOSE USED FOR LOAD CELL INSTALLATION

SECTION D-D TYPICAL ROCK BOLT LOAD CELL LAYOUT

(NOT TO SCALE)

NOTES:

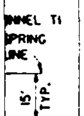
1. THE CONTRACTOR SHALL PROTECT THE (SPBX) EXTENSOMETERS REFERENCE HEADS, ROCK BOLT LOAD CELLS, AND (TX) TAPE EXTENSOMETER ANCHOR POINTS FROM BLAST, MECHANICAL, OR OTHER DAMAGE AS A RESULT OF CONSTRUCTION ACTIVITY, AND FROM BEING COVERED WITH SHOTCRETE.
2. INSTRUMENTS AND PROTECTIVE COVERS SHALL BE INSTALLED BEFORE SHOTCRETE IS APPLIED BY THE CONTRACTOR.
3. THE CONTRACTOR SHALL TAKE THE PRECAUTION, WHEN PLACING SHOTCRETE, TO PREVENT THE (SPBX) PROTECTIVE CAPS FOR THE (SPBX) EXTENSOMETERS, THE (TX) TAPE EXTENSOMETER ANCHOR POINTS, AND THE LOAD CELLS FROM BEING COVERED WITH SHOTCRETE.
4. ALL PROTECTIVE CAPS SHALL BE KEPT ON WHEN THE INSTRUMENTS ARE NOT BEING READ.
5. THE LOCATION OF INSTRUMENTS IS GIVEN ON DWG. NO. OIA-64/79 AND IN THE SPECIFICATIONS.
6. FIVE ARRAYS, AS SHOWN IN THE TUNNEL ℄ PROFILE, SECTIONS B-B, C-C AND D-D, CONSISTING OF 6 (SPBX) EXTENSOMETERS, 4 (TX) TAPE EXTENSOMETER ANCHOR POINTS, AND 2 ROCK BOLT LOAD CELLS TO BE WITHIN THE FIRST 1000 FEET OF TUNNELING AT LOCATIONS DIRECTED BY CONTRACTING OFFICER. ONE OF THESE ARRAYS TO BE LOCATED AT THE SAME STATION AS THE (MPBX) EXTENSOMETER, SEE DWG. NO. OIA-64/79.
7. 16 LOAD CELLS SHALL BE INSTALLED ON ROCK BOLTS DESIGNATED BY THE CONTRACTING OFFICER.



DETAIL A
(SPBX) EXTENSOMETER

(NOT TO SCALE)

NOTE: THE PROTECTIVE PVC CAP AS SHOWN FOR THE (SPBX) EXTENSOMETERS SHALL BE THE SAME PROTECTIVE PVC CAP FOR THE (TX) TAPE EXTENSOMETERS, A 6-INCH SCH-80 PVC PIPE WITH A SCREW-IN PVC PROTECTIVE CAP. SEE DETAIL A.



Revisions	Date	Description	By	Checked
3	2-3-94	AS CONSTRUCTED	S.B.D.	
2	29 JUN 89	DELETED NOTE 6 & RENAME NOTES 7 & 8.	B.F.	CED
1	31 MAY 89	CONFORMING TO REVIEW COMMENTS	LEWIS	CED

Graphic Scale

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NASHVILLE, TENNESSEE

UPPER CUMBERLAND RIVER BASIN
KENTUCKY AND TENNESSEE
LOCAL PROTECTION PROJECT
HARLAN, KENTUCKY
DIVERSION TUNNELS

INSTRUMENTATION SECTION & DETAILS

Designed By:	C. E. DAVIS
Drawn By:	LYLA LEWIS
Checked By:	Charles E Davis
Approved By:	CHIEF, GEOTECHNICAL BRANCH
Date:	MAY 1989
Drawing Number	OIA-64/80.3
FILE:	OIA64B80.DGN

Record Drawing as constructed dated

COMPUTER AIDED DESIGN & DRAFTING, SOILS SECTION

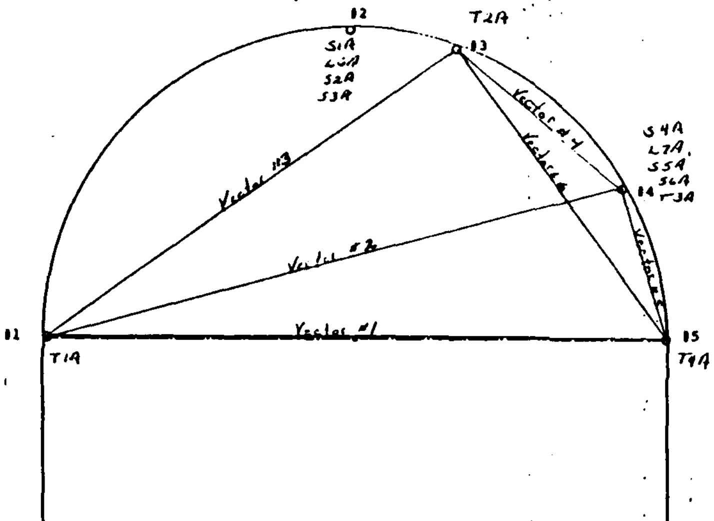
INSTRUMENTATION ARRAY LOCATION 11 DEC 90

Date Installed: 9/26/90

...son Installed: Bill Jonsberg

Project: Harlan Diversion

Contractor: Grassetto-Incisa



Please note these are the corrected stations and elevations on Array "A" as of 12/4/90 Tom Trapp

TAPE EXTENSOMETER POINTS

Location	Station	Elevation
1	10+83	1176.2
3	10+83	1187.1
4	10+83	1179.2
5	10+83	1176.2

LOAD CELL POSITIONS

Location	Station	Elevation
2	10+77	1188.17
4	10+77	1179.17

TUNNEL# 1

STATION 10+77

ARRAY A

SPBX POSITIONS

Location	Station	Elevation
2	10+75	1188.15
2	10+79	1188.19
2	10+81	1188.21
4	10+75	1179.15
4	10+79	1179.19
4	10+81	1179.21

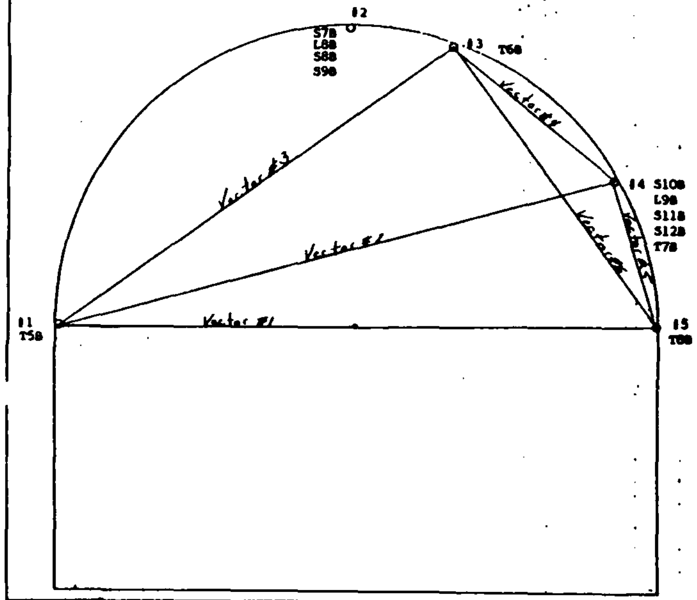
INSTRUMENTATION ARRAY LOCATION 01 NOV 90

Date Installed: 10/27/90

...rson Installed: Tom Trapp

Project: Harlan Diversion

Contractor: Grassetto-Incisa



TAPE EXTENSOMETER POINTS

Location	Station	Elevation
1	13+72.5	1172.99
3	13+72.5	1188.69
4	13 72.5	1180.99
5	13 72.5	1172.99

LOAD CELL POSITIONS

Location	Station	Elevation
2	13+67	1189.95
4	13+67	1180.99

TUNNEL# 1

STATION 13+67

ARRAY B

SPBX POSITIONS

Location	Station	Elevation
2	13+65	1189.94
2	13+69	1189.96
2	13+71	1189.98
4	13+65	1180.94
4	13+69	1180.96
4	13+71	1180.98

PLATE I-3

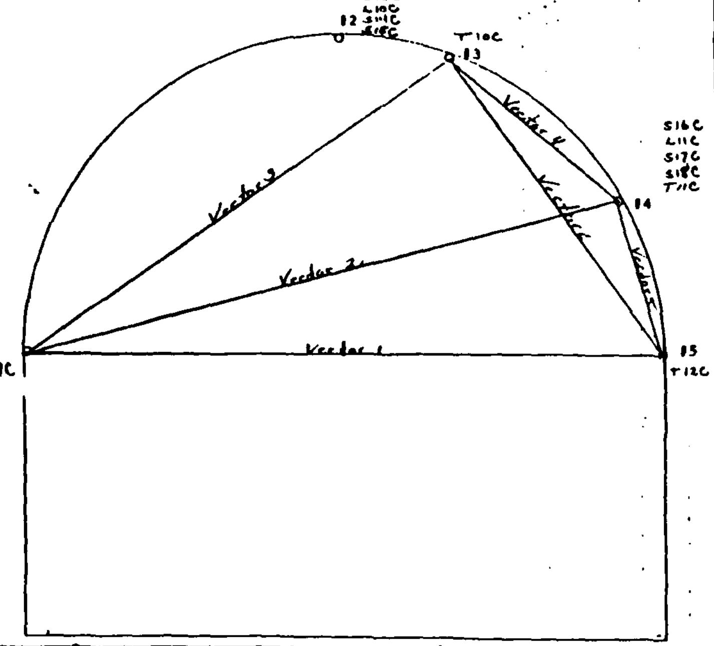
INSTRUMENTATION ARRAY LOCATION

Date Installed: 11/14/90

Person Installed: Tom TRAPP

Project: Harlan Diversion

Contractor: Grassetto-Incisa



TAPE EXTENSOMETER POINTS		
Location	Station	Elevation
1	16+03.5	1174.41
3	"	1190.31
4	"	1182.41
5	"	1174.41

LOAD CELL POSITIONS		
Location	Station	Elevation
2	15+98	1191.37
4	15+98	1182.37

TUNNEL# 1

STATION 15+98

ARRAY C

SPBX POSITIONS		
Location	Station	Elevation
2	15+96	1191.36
2	16+00	1191.38
2	16+02	1191.41
4	15+96	1182.36
4	16+00	1182.38
4	16+02	1182.41

INSTRUMENTATION ARRAY LOCATION

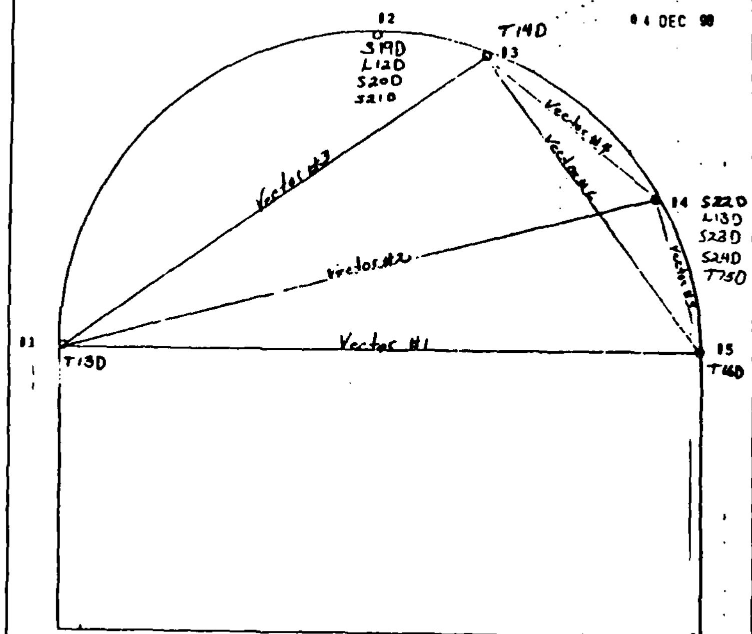
Date Installed: 11/27/90

Person Installed: Tom Trapp

Project: Harlan Diversion

Contractor: Grassetto-Incisa

4 DEC 90



TAPE EXTENSOMETER POINTS		
Location	Station	Elevation
1	11+31.5	1171.51
3	"	1187.41
4	"	1179.50
5	"	1171.51

LOAD CELL POSITIONS		
Location	Station	Elevation
2	11+26	1188.47
4	11+26	1179.47

TUNNEL# 2

STATION 11+26

ARRAY D

SPBX POSITIONS		
Location	Station	Elevation
2	11+24	1188.46
2	11+28	1188.47
2	11+30	1188.48
4	11+24	1179.46
4	11+28	1178.47
4	11+30	1179.48

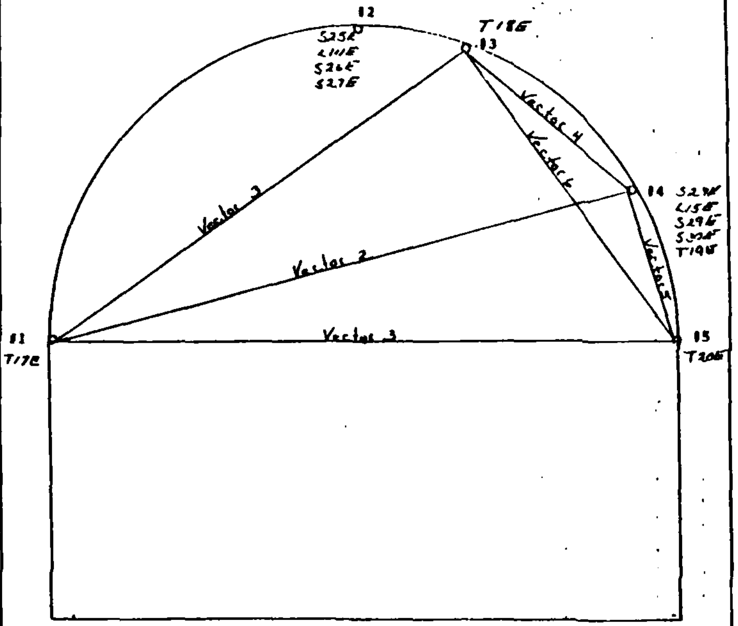
PLATE I-4

10 DEC 90

INSTRUMENTATION ARRAY LOCATION

Date Installed: 12/6/90 — Project: Harlan Diversion

Person Installed: Tom Trapp — Contractor: Grassetto-Incisa



TAPE EXTENSOMETER POINTS		
Location	Station	Elevation
1	18+78.5	1126.07
3	18+73.5	1192.77
4	18+73.5	1184.07
5	18+73.5	1176.07

LOAD CELL POSITIONS		
Location	Station	Elevation
2	18+68	1193.03
4	18+68	1184.03

TUNNEL# 1

STATION 18+68

ARRAY E

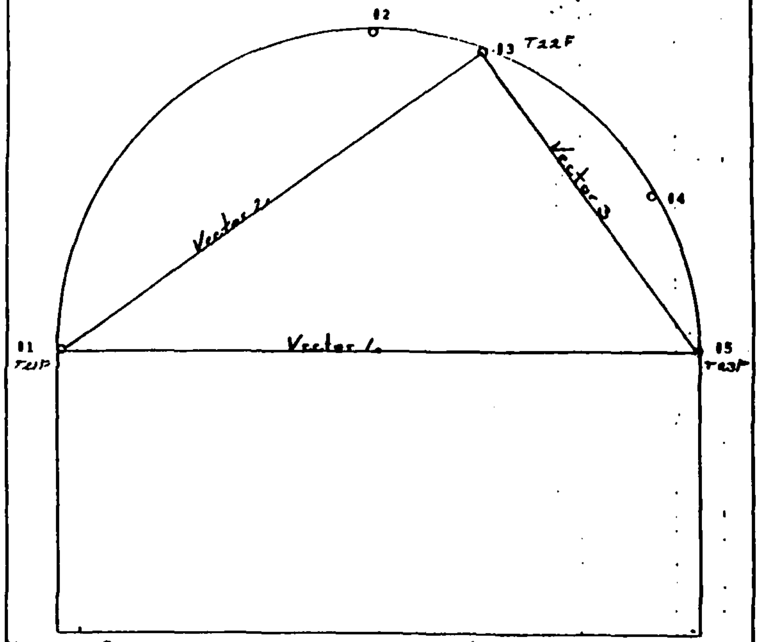
SPBX POSITIONS		
Location	Station	Elevation
2	18+66	1193.02
2	18+70	1193.04
2	18+72	1193.05
4	18+66	1184.02
4	18+70	1184.04
4	18+72	1184.05

7 FEB 9

INSTRUMENTATION ARRAY LOCATION

Date Installed: 2/5/91 — Project: Harlan Diversion

Person Installed: Tom Trapp — Contractor: Grassetto-Incisa



TAPE EXTENSOMETER POINTS		
Location	Station	Elevation
1	15+33	1173.99
3	15+33	1189.[illegible]
5	15+33	1173.9[illegible]

LOAD CELL POSITIONS		
Location	Station	Elevation

TUNNEL# 2

STATION 15+33

ARRAY F

SPBX POSITIONS		
Location	Station	Elevation

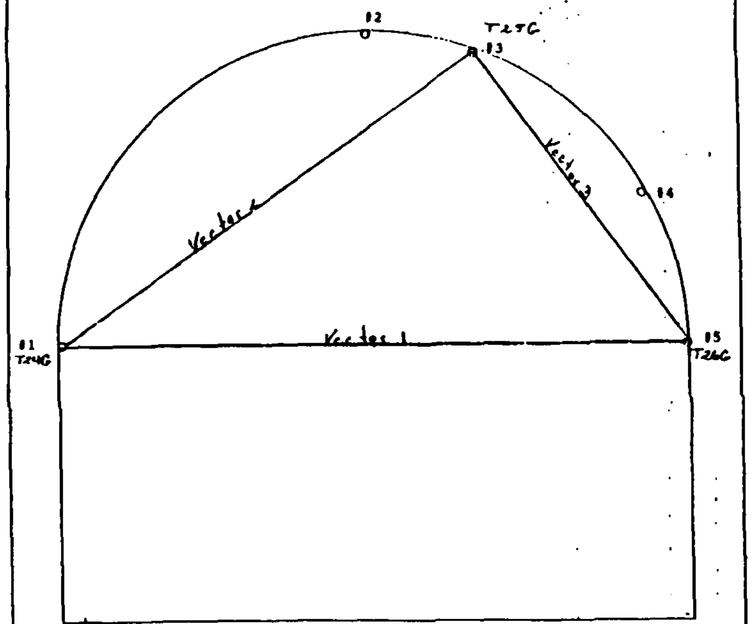
PLATE I-5

11 FEB 91

INSTRUMENTATION ARRAY LOCATION

Date Installed: 2/8/91 Project: Harlan Diversion

Person Installed: Tom TRAPP Contractor: Grassetto-Incisa



TAPE EXTENSOMETER POINTS		
Location	Station	Elevation
1	25+55	1180.2
3	25+55	1196.2
5	25+55	1180.3

LOAD CELL POSITIONS		
Location	Station	Elevation

TUNNEL# 1

STATION 25+55

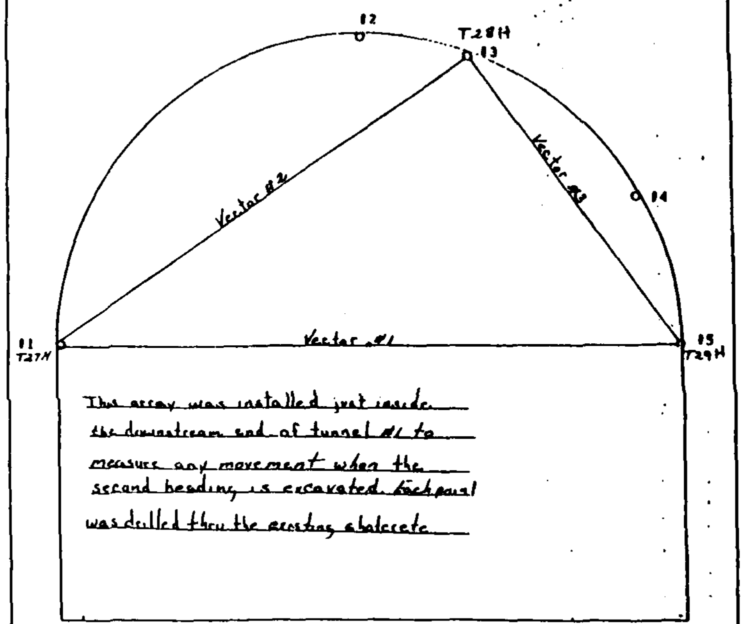
ARRAY G

SPBX POSITIONS		
Location	Station	Elevation

INSTRUMENTATION ARRAY LOCATION

Date Installed: 3/13/91 Project: Harlan Diversion

Person Installed: Tom TRAPP Contractor: Grassetto-Incisa



This array was installed just inside the downstream end of tunnel #1 to measure any movement when the second heading is excavated. Each pin was drilled thru the existing shotcrete

TAPE EXTENSOMETER POINTS		
Location	Station	Elevation
1	9+95	1170.6
3	9+95	1186.6
5	9+95	1170.6

LOAD CELL POSITIONS		
Location	Station	Elevation

TUNNEL# 1

STATION 9+95

ARRAY H

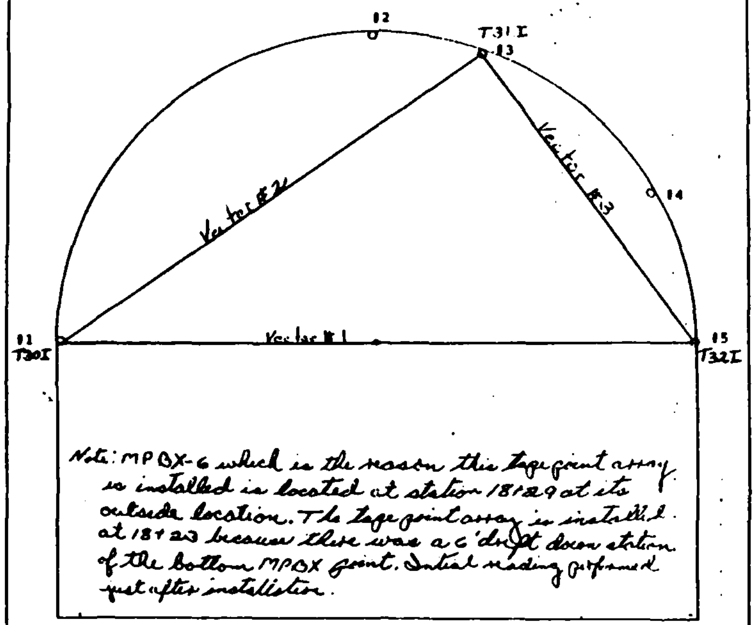
SPBX POSITIONS		
Location	Station	Elevation

PLATE I-6

INSTRUMENTATION ARRAY LOCATION 9 MAY 91

Date Installed: 5/7/90 Project: Marian Diversion

Person Installed: T. Trapp/R. Fugale Contractor: Grassetto-Incisa



TAPE EXTENSOMETER POINTS		
Location	Station	Elevation
1	18+23	1175.75
3	18+23	1194.65
5	18+23	1175.75

LOAD CELL POSITIONS		
Location	Station	Elevation
—	—	—
—	—	—

TUNNEL: 3

STATION 18+23

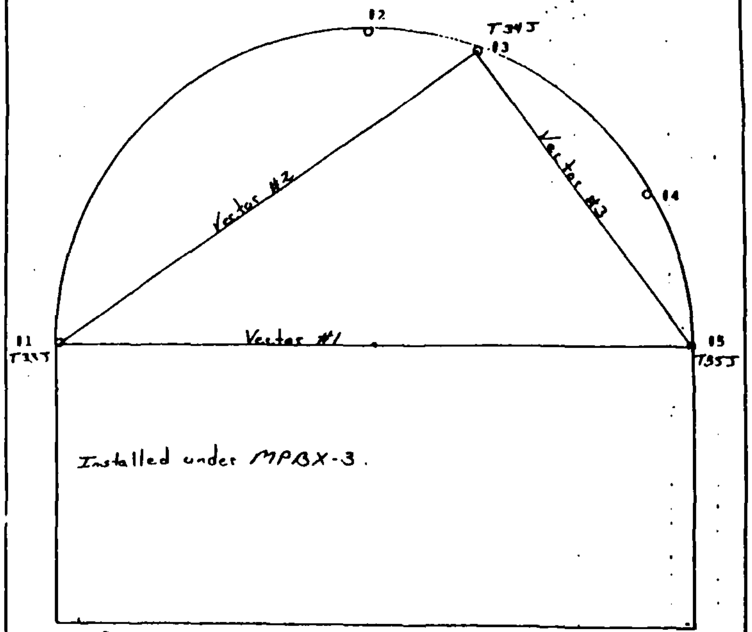
ARRAY I

SPBX POSITIONS		
Location	Station	Elevation
—	—	—
—	—	—
—	—	—
—	—	—
—	—	—
—	—	—

INSTRUMENTATION ARRAY LOCATION 3 JUL 91

Date Installed: 6/8/91 Project: Marian Diversion

Person Installed: Tom Trapp Contractor: Grassetto-Incisa



TAPE EXTENSOMETER POINTS		
Location	Station	Elevation
1	22+11	1199.05
3	22+11	1178.15
5	22+11	1178.15

LOAD CELL POSITIONS		
Location	Station	Elevation

TUNNEL: 3

STATION 22+10

ARRAY J

SPBX POSITIONS		
Location	Station	Elevation

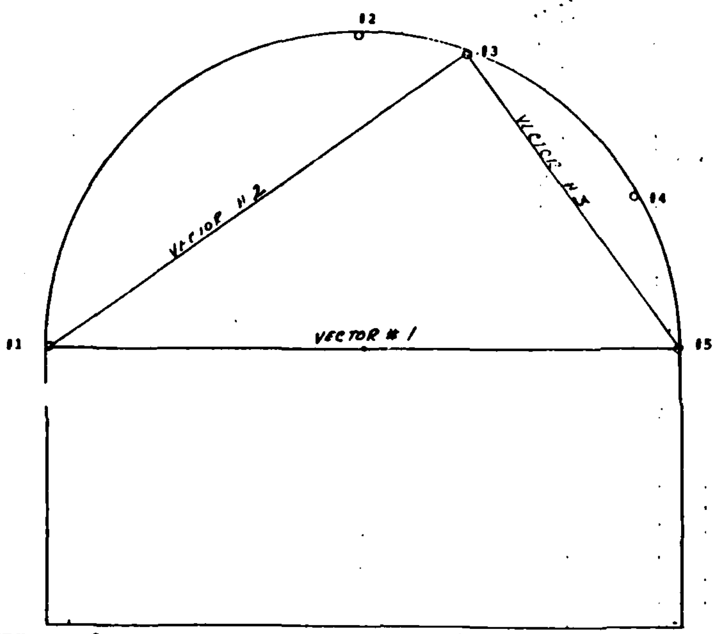
PLATE I-7

PLATE I-8

INSTRUMENTATION ARRAY LOCATION

Date Installed: 6-12-91 Project: Harlan Diversion

[illegible]on Installed: Juan Osborne Contractor: Grassetto-Incisa



TAPE EXTENSOMETER POINTS		
Location	Station	Elevation
1	11+36	1171.93
2	11+36	118[illegible].43
3	11+36	1187.43

LOAD CELL POSITIONS		
Location	Station	Elevation

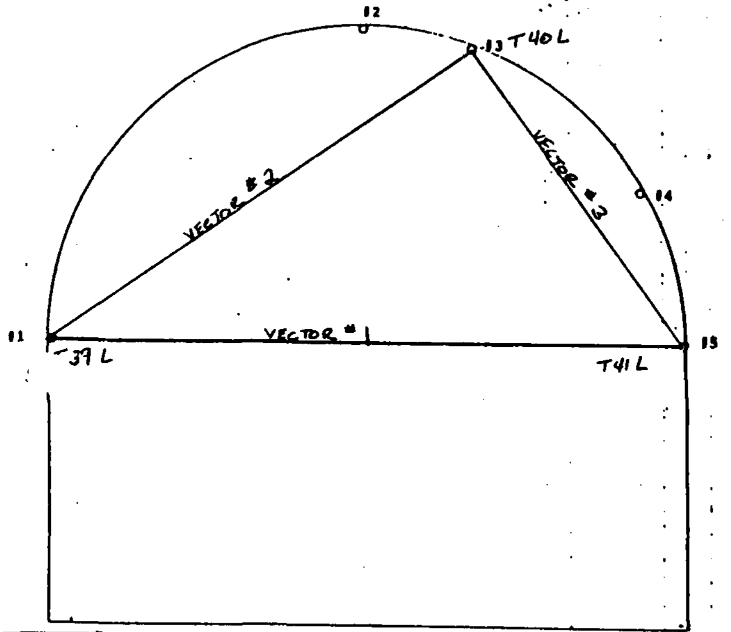
TUNNEL: 3
STATION 11+36
ARRAY K

SPBX POSITIONS		
Location	Station	Elevation

INSTRUMENTATION ARRAY LOCATION

Date Installed: 8/27/91 Project: Harlan Diversion

Pe[illegible] Installed: TRAPP/COLLINS Contractor: Grassetto-Incisa



TAPE EXTENSOMETER POINTS		
Location	Station	Elevation
1	26+52	1160.87
3	26+52	1194.37
5	26+52	1180.87

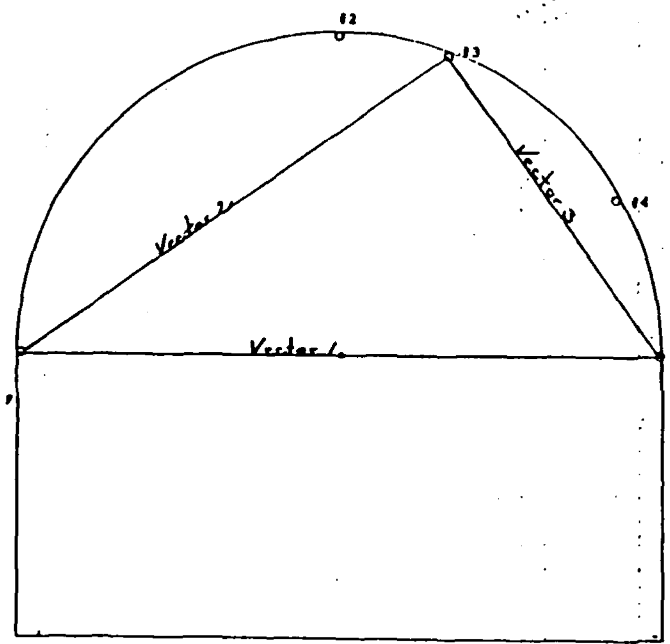
LOAD CELL POSITIONS		
Location	Station	Elevation

TUNNEL: 2
STATION 26+52
ARRAY L

SPBX POSITIONS		
Location	Station	Elevation

INSTRUMENTATION ARRAY LOCATION

Date Installed: 10/9/91
on Installed:
Project: Marian Diversion
Contractor: Grassetto-Indisa



TAPE EXTENSOMETER POINTS

Location	Station	Elevation
	13+82	
1	13+82	
5	13+82	

LOAD CELL POSITIONS

Location	Station	Elevation

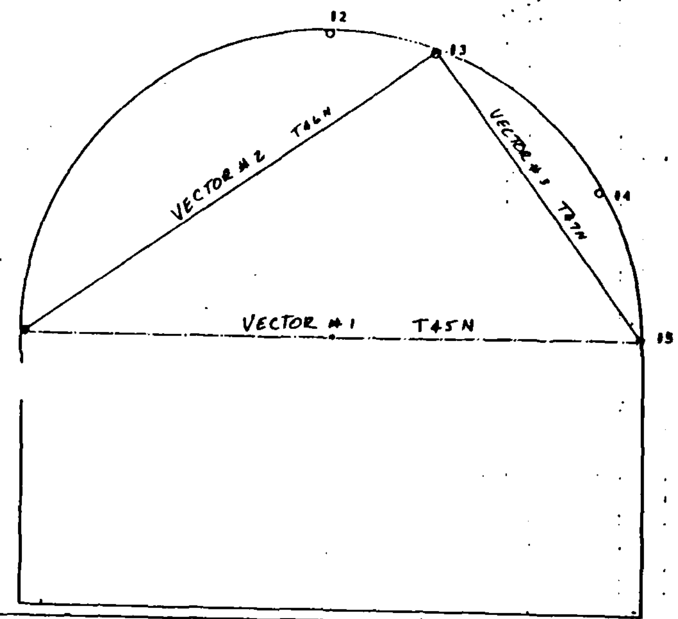
TUNNEL: 4
STATION 13+82
ARRAY M

SPBX POSITIONS

Location	Station	Elevation

INSTRUMENTATION ARRAY LOCATION

Date Installed: 17 Nov 91
n Installed: June Osborne
Project: Marian Diversion
Contractor: Grassetto-Indisa



TAPE EXTENSOMETER POINTS

Location	Station	Elevation
1	15+97	
1	15+97	
5	15+97	

LOAD CELL POSITIONS

Location	Station	Elevation

TUNNEL: T4
STATION 15+97
ARRAY N

SPBX POSITIONS

Location	Station	Elevation

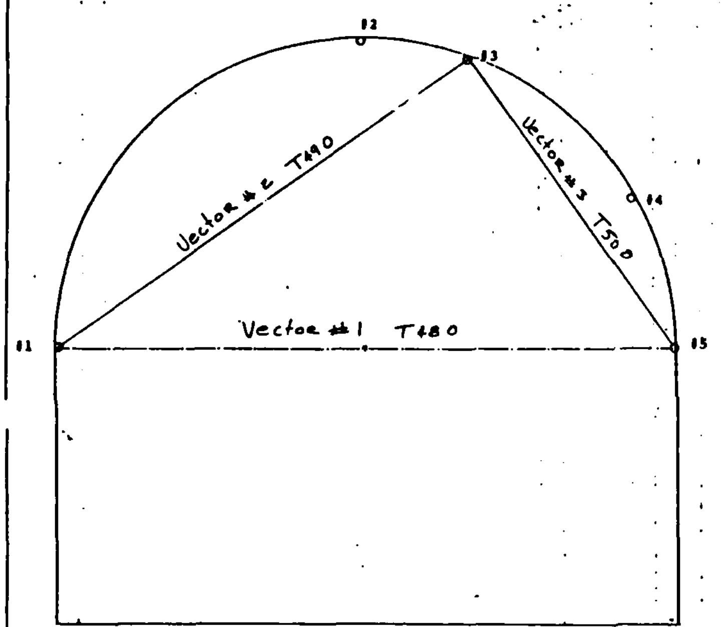
PLATE I-9

PLATE I-10

INSTRUMENTATION ARRAY LOCATION

Date Installed: 11 Dec 91 Project: Harlan Diversion

rson Installed: Tom Trapp Contractor: Grassetto-Incisa



TAPE EXTENSOMETER POINTS		
Location	Station	Elevation
1	19+23	
2	19+23	
3	19+23	

LOAD CELL POSITIONS		
Location	Station	Elevation

TUNNEL: T4

STATION 19+23

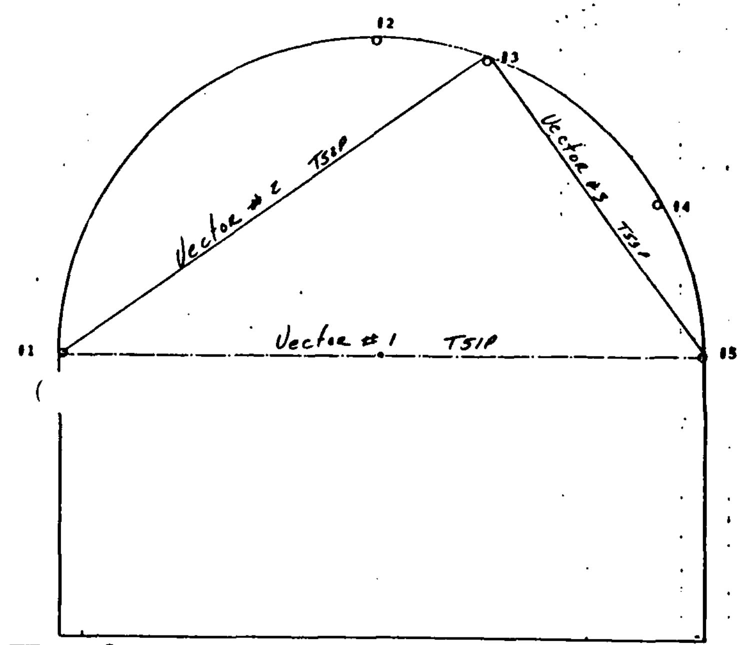
ARRAY 0

SPBX POSITIONS		
Location	Station	Elevation

INSTRUMENTATION ARRAY LOCATION

Date Installed: 17 Feb 92 Project: Harlan Diversion

Pe Installed: J. Osborne Contractor: Grassetto-Incisa



TAPE EXTENSOMETER POINTS		
Location	Station	Elevation
1	23+9[illegible]	
3	23+9[illegible]	
5	23+9[illegible]	

LOAD CELL POSITIONS		
Location	Station	Elevation

TUNNEL: T4

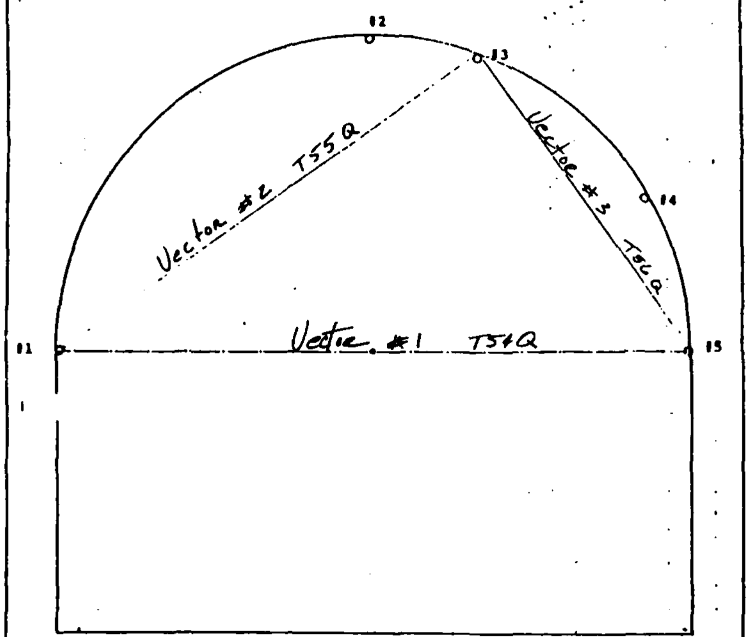
STATION 23+96

ARRAY P

SPBX POSITIONS		
Location	Station	Elevation

INSTRUMENTATION ARRAY LOCATION

Date Installed: 06 Mar 92
Person Installed: Team
Project: Marian Diversion
Contractor: Grassetto-Incisa



TAPE EXTENSOMETER POINTS		
Location	Station	Elevation
1	27+37	
2	27+37	
3	27+37	

LOAD CELL POSITIONS		
Location	Station	Elevation

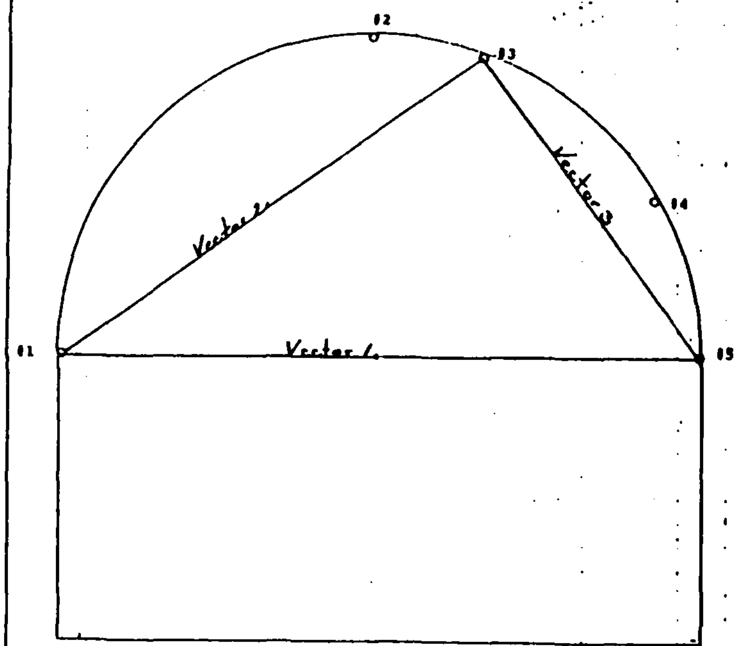
TUNNEL: T4
STATION 27+37
ARRAY Q

SPBX POSITIONS		
Location	Station	Elevation

7 FEB 92

INSTRUMENTATION ARRAY LOCATION

Date Installed: 3/17/92
on Installed:
Project: Marian Diversion
Contractor: Grassetto-Incisa



TAPE EXTENSOMETER POINTS		
Location	Station	Elevation
1	29+05	
2	29+05	
3	29+05	

LOAD CELL POSITIONS		
Location	Station	Elevation

TUNNEL: 4
STATION 29+05
ARRAY R

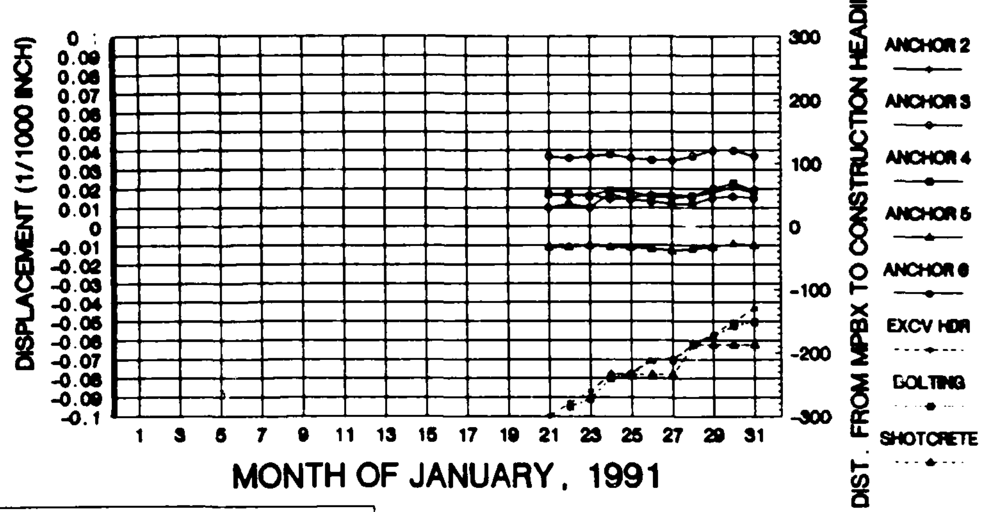
SPBX POSITIONS		
Location	Station	Elevation

PLATE I-11

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-1



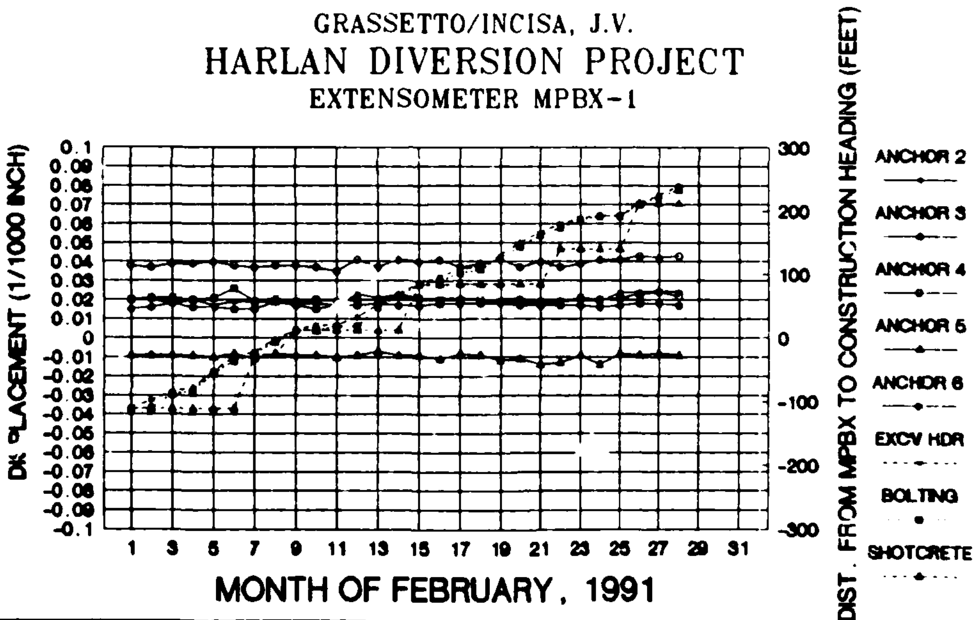
TUNNEL #1
STATION 25+55
ELEVATION OF REFERENCE HEAD = 1475.92

ZERO IS INITIAL READING.
AS OF 1/28 THE PLOTS HAVE BEEN CORRECTED.

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-1



TUNNEL #1
STATION 25+55
ELEVATION OF REFERENCE HEAD = 1475.92

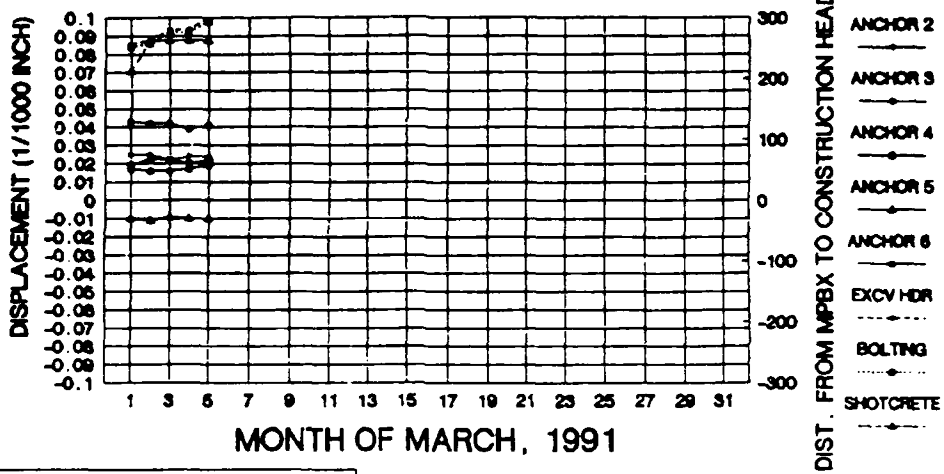
ZERO IS INITIAL READING.

PLATE I-12

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-1



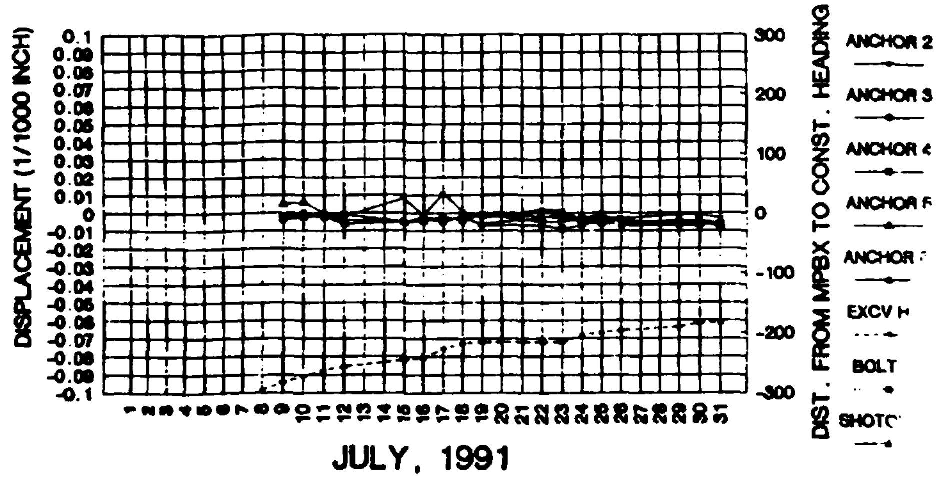
TUNNEL #1
STATION 25+55
ELEVATION OF REFERENCE HEAD = 1475.92

ZERO IS INITIAL READING.

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-2



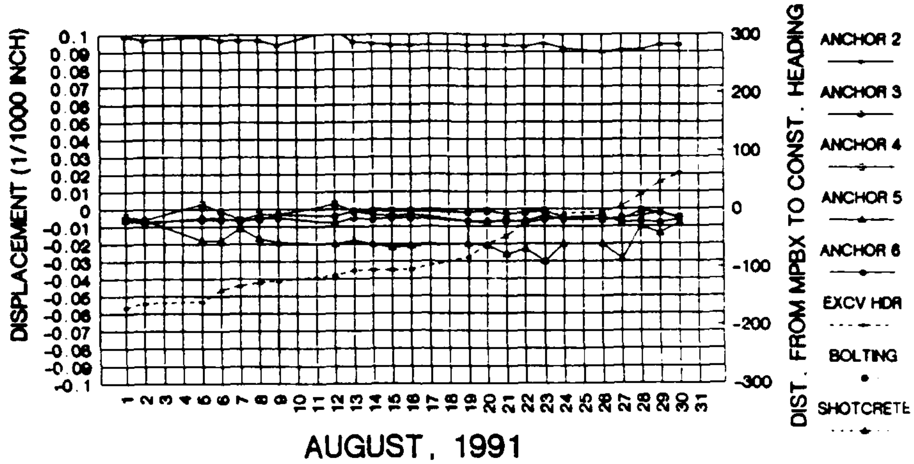
NOTED ERRATIC READINGS ON 6/24.
ZERO IS INITIAL READING FOR ALL POINTS.
TUNNEL #2 / STATION 29+43

INSTRUMENT WAS REPAIRED AND REINITIALIZED 7/
PAUL ROSS REPAIRED INSTRUMENT ON 7/6.
STARTING ON 7/9 IS NEW SET OF NUMBERS

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-2



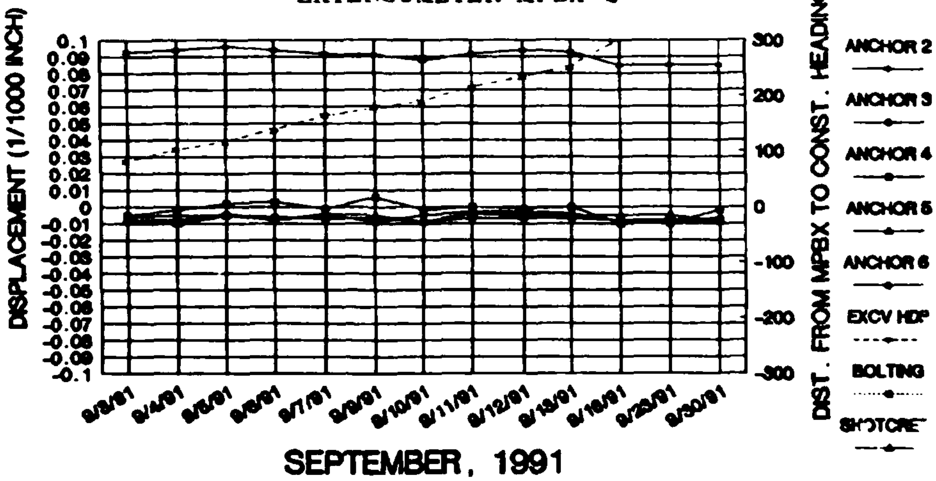
NOTED ERRATIC READINGS ON 6/24.
ZERO IS INITIAL READING FOR ALL POINTS.
TUNNEL #2 / STATION 26+43

INSTRUMENT WAS REPAIRED AND REINITIALIZED 7/8
PAUL ROSS REPAIRED INSTRUMENT ON 7/6.
STARTING ON 7/9 IS NEW SET OF NUMBERS.

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-2



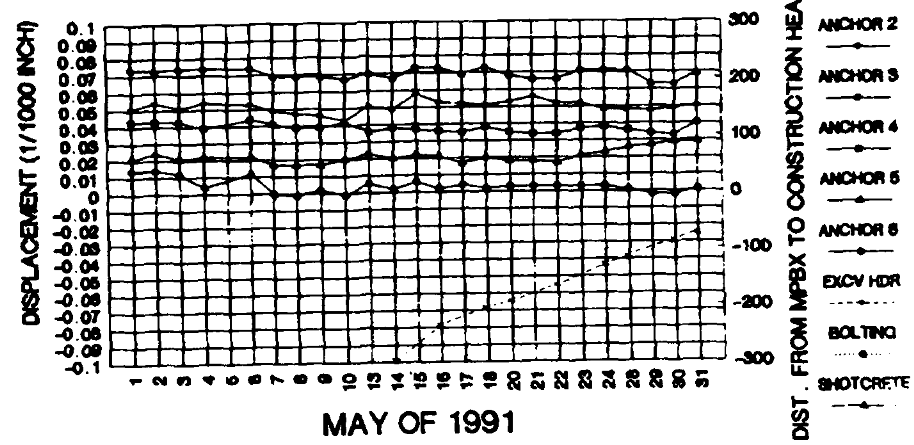
NOTED ERRATIC READINGS ON 6/24.
ZERO IS INITIAL READING FOR ALL POINTS.
TUNNEL #2 / STATION 26+43

INSTRUMENT WAS REPAIRED AND REINITIALIZED
PAUL ROSS REPAIRED INSTRUMENT ON 7/6.
STARTING ON 7/9 IS NEW SET OF NUMBERS.

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-3



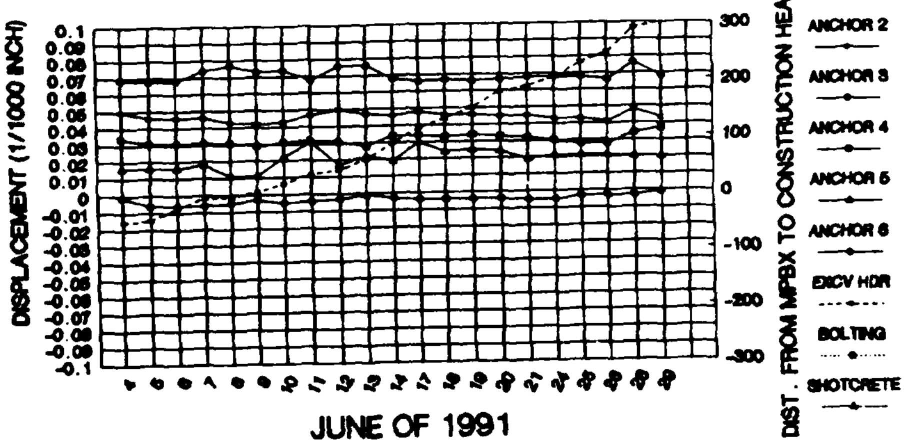
TUNNEL #3
STATION 22+10.6
ELEVATION OF REFERENCE HEAD = 1410.56

ZERO IS INITIAL REA...

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-3



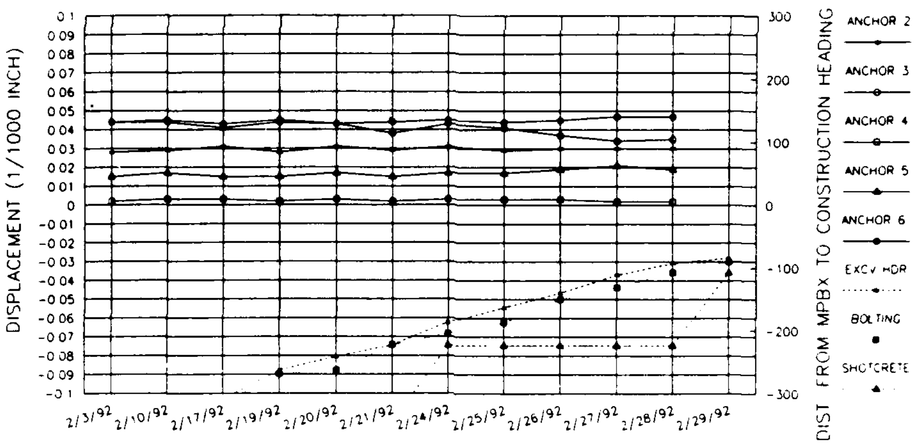
TUNNEL #3
STATION 22+10.6
ELEVATION OF REFERENCE HEAD = 1410.56

ZERO IS INITIAL READING.

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-4



FEBRUARY, 1992

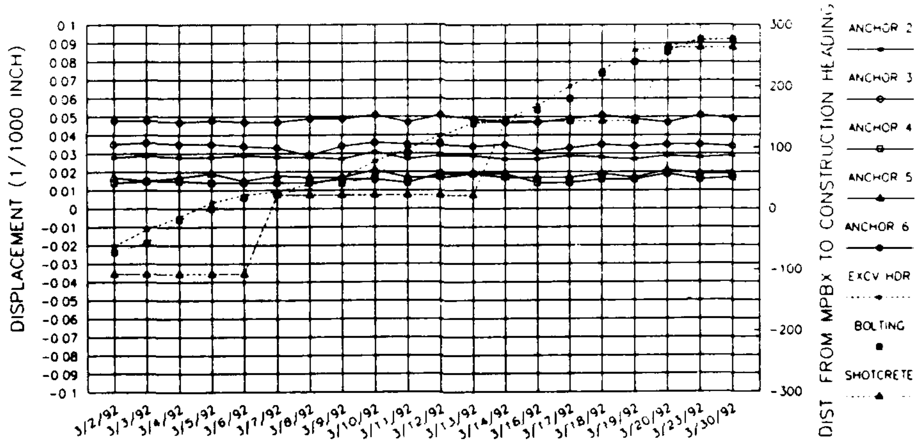
TUNNEL #4
STATION 27+24.7
ELEVATION OF REFERENCE HEAD = 1443.02

ZERO IS INITIAL READING

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-4



MARCH, 1992

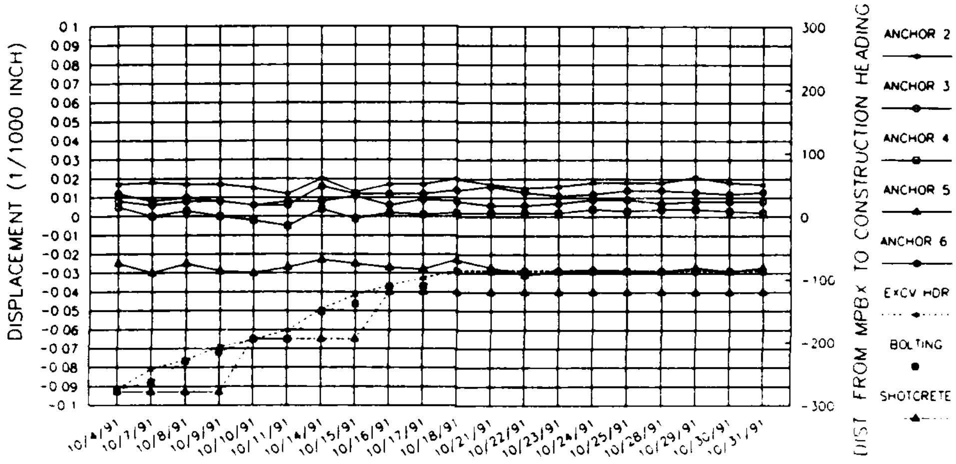
TUNNEL #4
STATION 27+24.7
ELEVATION OF REFERENCE HEAD = 1443.02

ZERO IS INITIAL READING

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-5



OCTOBER OF 1991

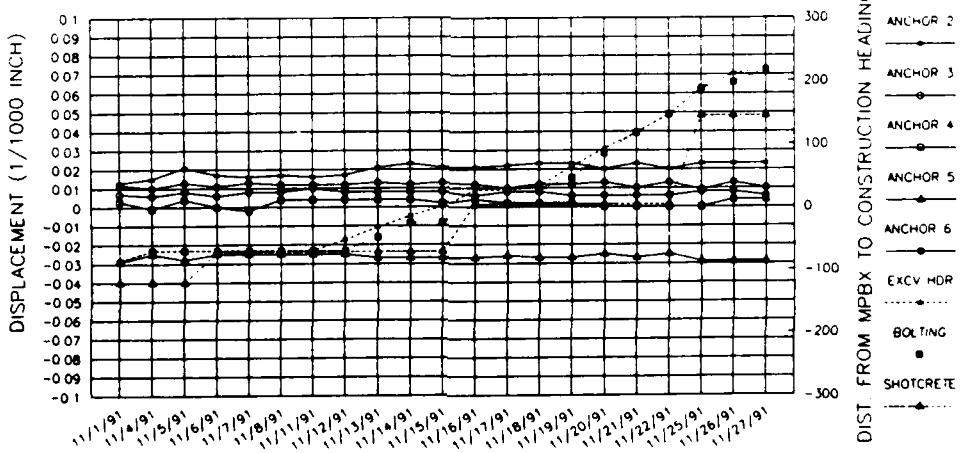
TUNNEL #4
STATION 15+93.4
ELEVATION OF REFERENCE HEAD = 1438.67

ZERO IS INITIAL READING

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-5



NOVEMBER, 1991

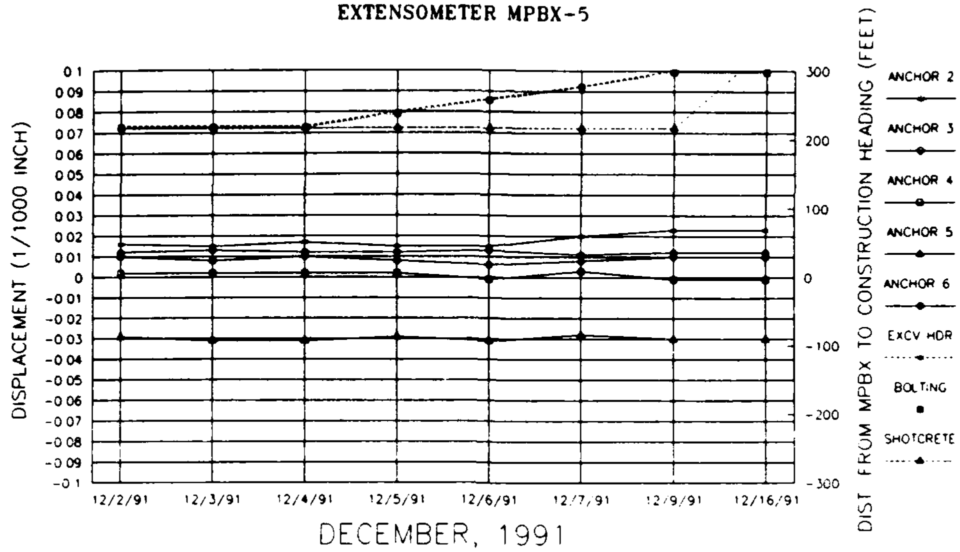
TUNNEL #4
STATION 15+93.4
ELEVATION OF REFERENCE HEAD = 1438.67

ZERO IS INITIAL READING

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-5



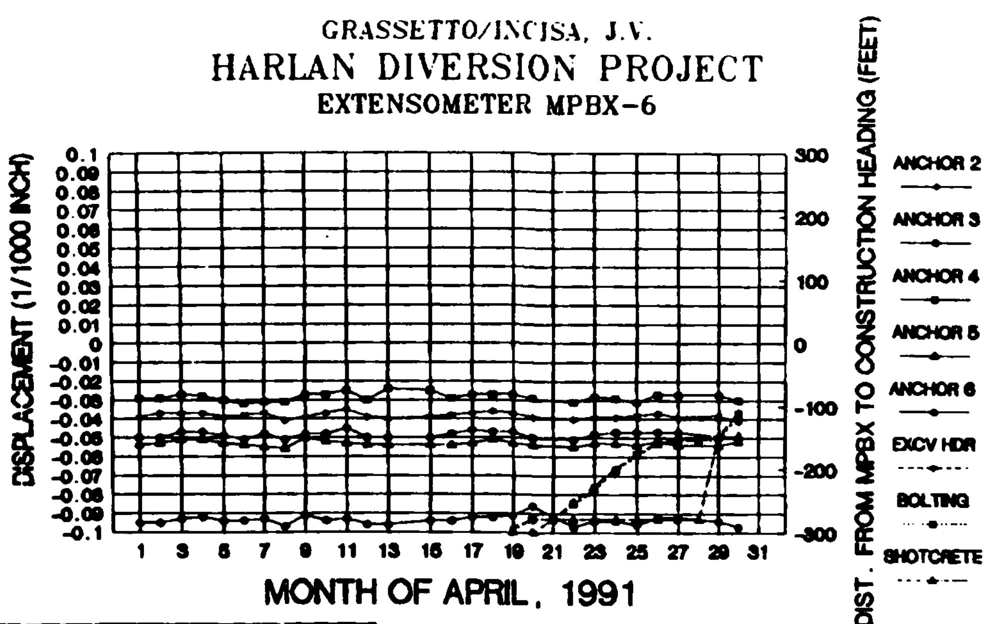
TUNNEL #4
STATION 15+93.4
ELEVATION OF REFERENCE HEAD = 1438.67

ZERO IS INITIAL READING

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-6



TUNNEL #3
STATION 18+29
ELEVATION OF REFERENCE HEAD = 1487.67

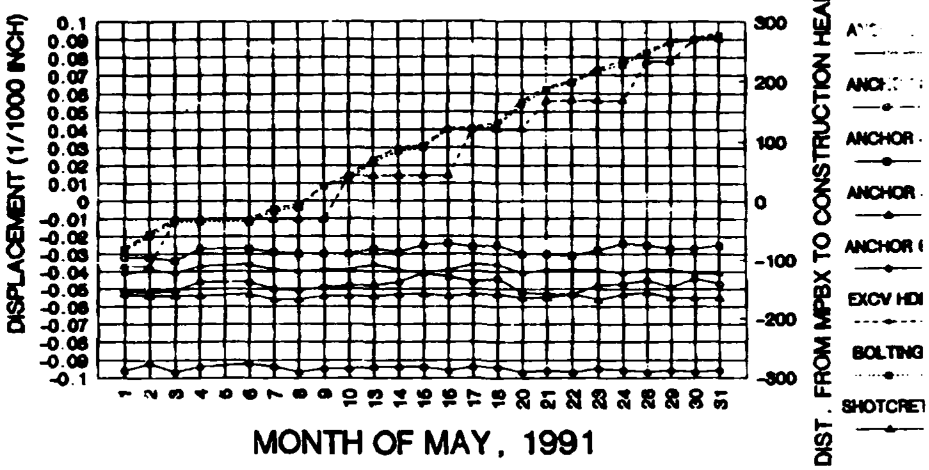
ZERO IS INITIAL READING.

PLATE I-18

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-6



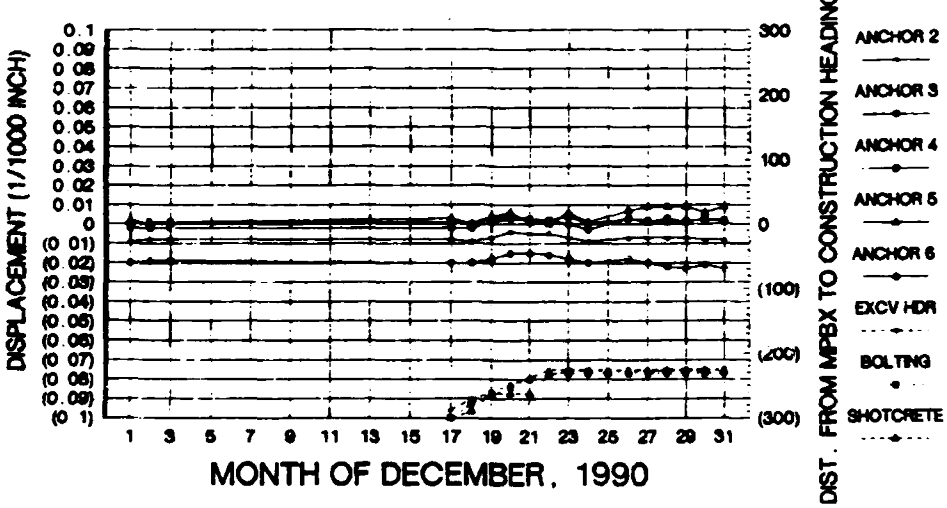
TUNNEL #3
STATION 18+29
ELEVATION OF REFERENCE HEAD = 1487.67

ZERO IS INITIAL READING

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-7



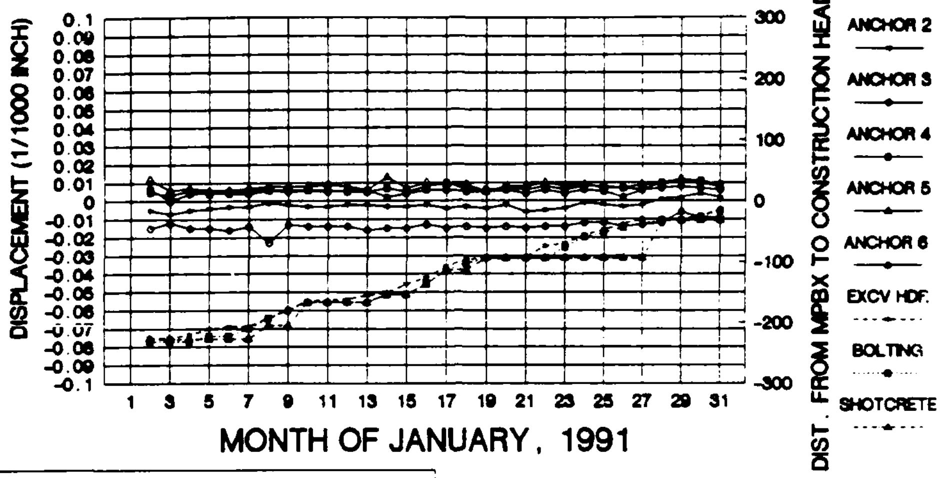
ON 12/17 TUNNEL 2 INITIATED MPBX-7 FOR DAILY READINGS

ON 12/22/90 PROJECT WAS SHUT DOWN UNTIL 1/2/91

GRASSETTO/INCISA, J.V.

HARLAN DIVERSION PROJECT

EXTENSOMETER MPBX-7



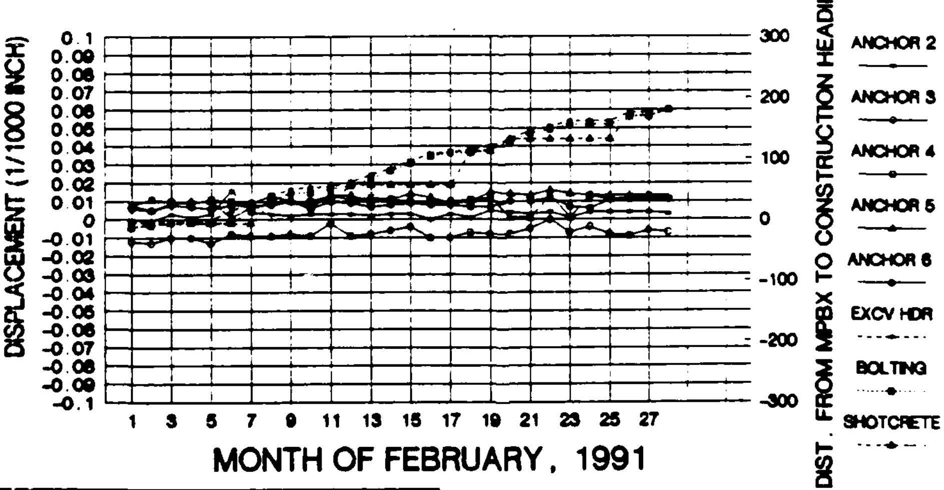
ON 12/17/90 TUNNEL 2 INITIATED MPBX-7 FOR DAILY READINGS.
TUNNEL #2 / STATION 15+33

NO READING WAS TAKEN ON 1/1/91.
ZERO IS INITIAL READING FOR ALL POINTS.

GRASSETTO/INCISA, J.V.

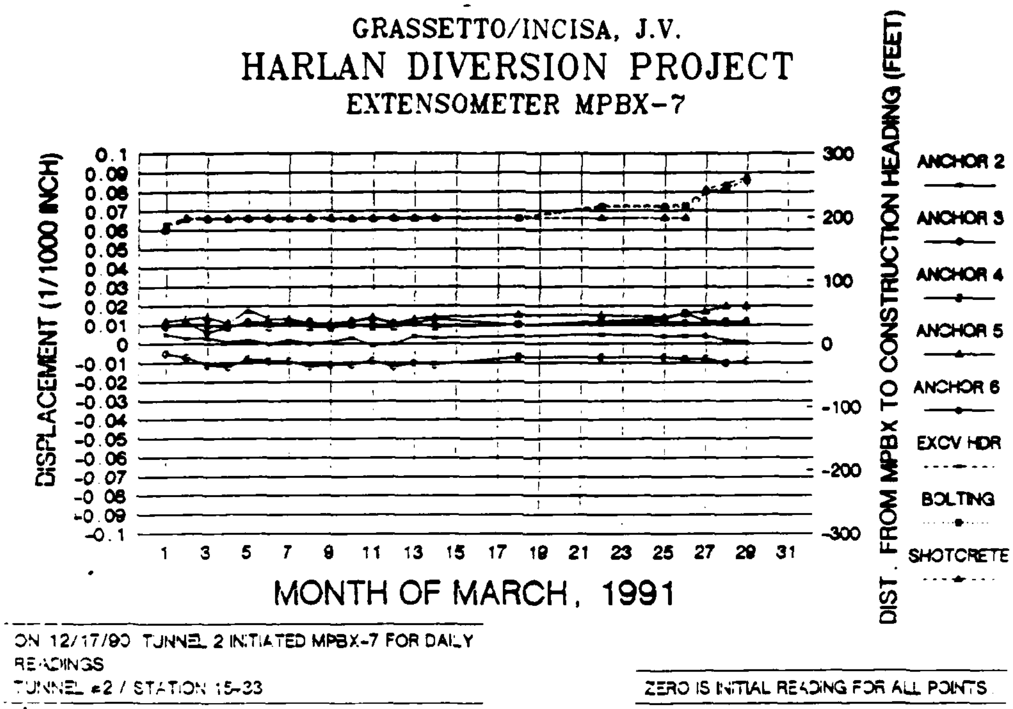
HARLAN DIVERSION PROJECT

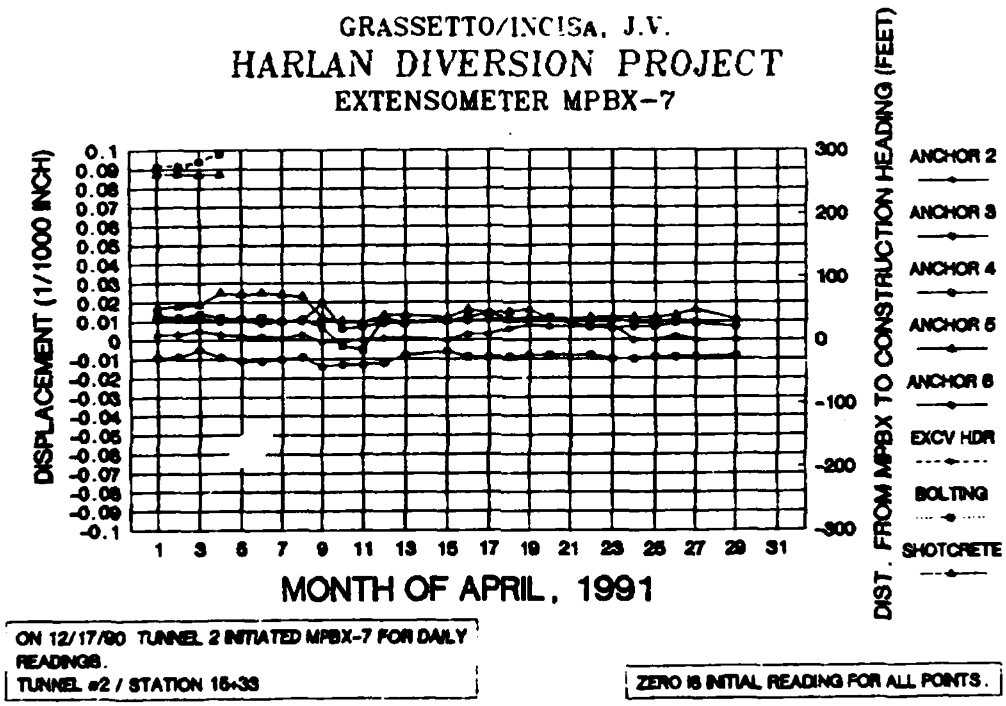
EXTENSOMETER MPBX-7



ON 12/17/90 TUNNEL 2 INITIATED MPBX-7 FOR DAILY READINGS.
TUNNEL #2 / STATION 15+33

ZERO IS INITIAL READING FOR ALL POINTS.

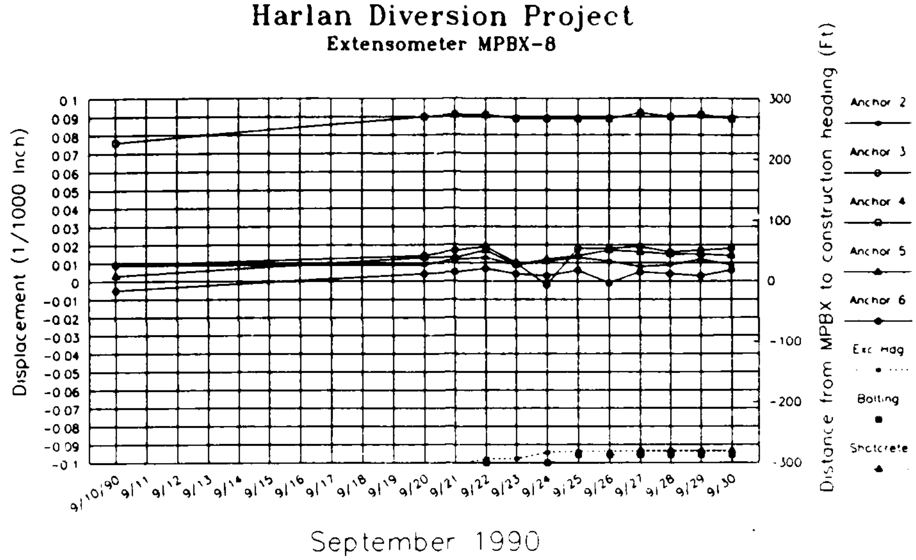

GRASSETTO/INCISA, J.V.
HARLAN DIVERSION PROJECT
EXTENSOMETER MPBX-7
DISPLACEMENT (1/1000 INCH)
DIST. FROM MPBX TO CONSTRUCTION HEADING (FEET)
ANCHOR 2
ANCHOR 3
ANCHOR 4
ANCHOR 5
ANCHOR 6
EXCV HDR
BOLTING
SHOTCRETE
MONTH OF MARCH, 1991
ON 12/17/90 TUNNEL 2 INITIATED MPBX-7 FOR DAILY READINGS
TUNNEL #2 / STATION 15+33
ZERO IS INITIAL READING FOR ALL POINTS


GRASSETTO/INCISA, J.V.
HARLAN DIVERSION PROJECT
EXTENSOMETER MPBX-7
DISPLACEMENT (1/1000 INCH)
DIST. FROM MPBX TO CONSTRUCTION HEADING (FEET)
ANCHOR 2
ANCHOR 3
ANCHOR 4
ANCHOR 5
ANCHOR 6
EXCV HDR
BOLTING
SHOTCRETE
MONTH OF APRIL, 1991
ON 12/17/90 TUNNEL 2 INITIATED MPBX-7 FOR DAILY READINGS.
TUNNEL #2 / STATION 15+33
ZERO IS INITIAL READING FOR ALL POINTS.

Grassetto/Incisa, J.V.

Harlan Diversion Project

Extensometer MPBX-8



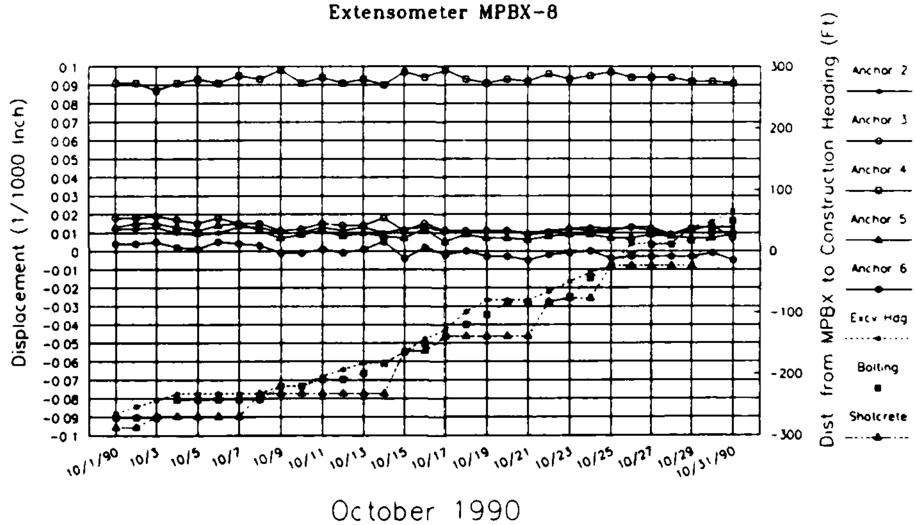
Tunnel #1
Station 13+65
Elevation Reference Head = 1415.43

Zero is initial reading

Grassetto/Incisa, J.V.

Harlan Diversion Project

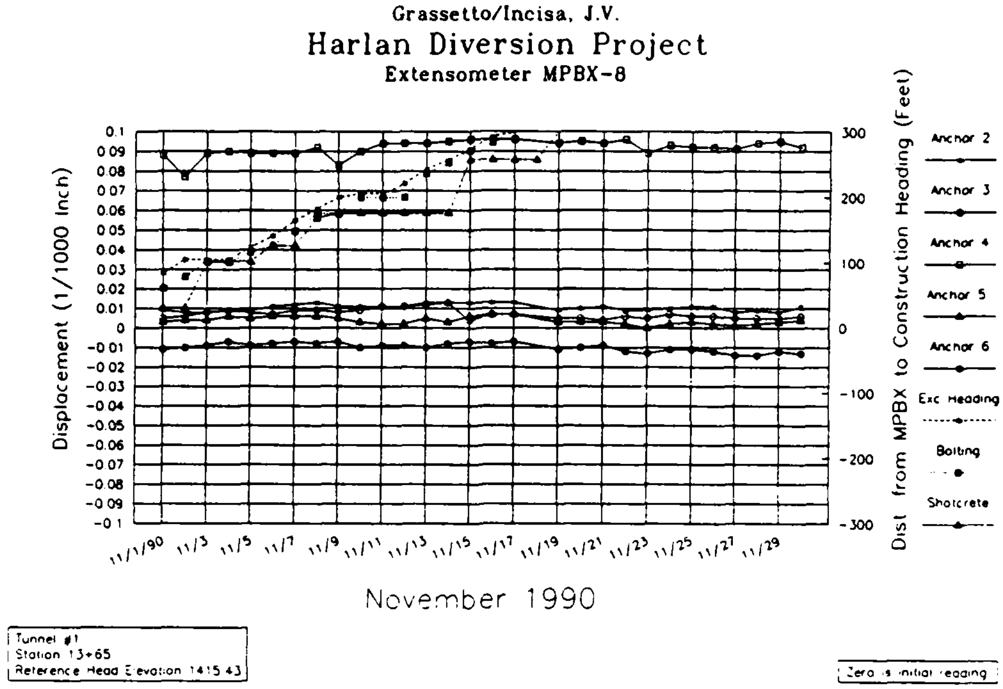
Extensometer MPBX-8



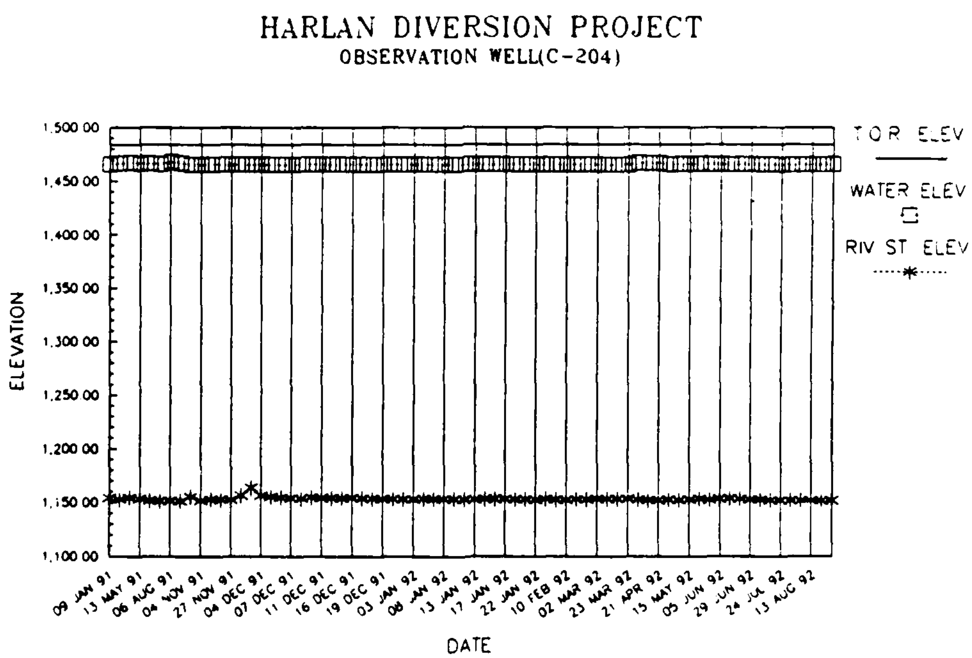
Tunnel #1
Station 13+65
Reference Head Elevation 1415.43

Zero is initial reading

PLATE I-22



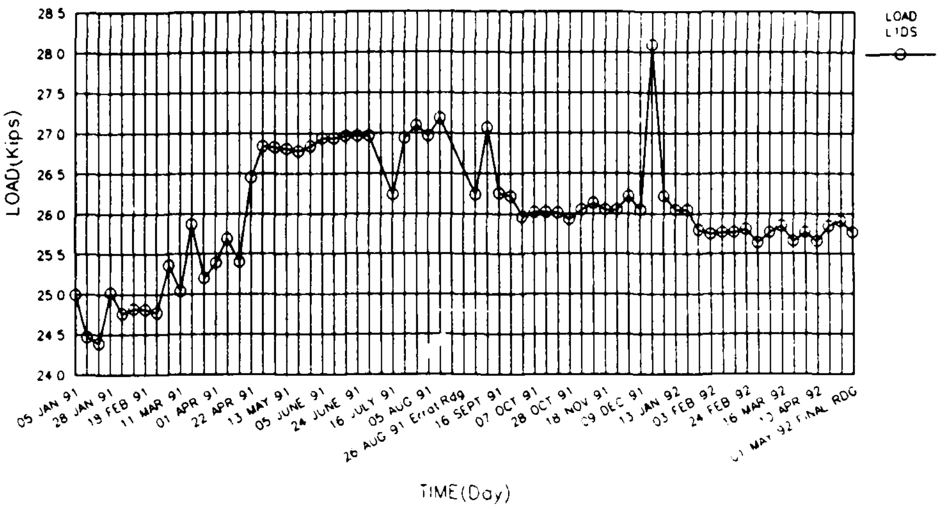
Grassetto/Incisa, J.V.
Harlan Diversion Project
Extensometer MPBX-8
Displacement (1/1000 Inch)
Dist from MPBX to Construction Heading (Feet)
Anchor 2
Anchor 3
Anchor 4
Anchor 5
Anchor 6
Exc Heading
Bolting
Shotcrete
November 1990
Tunnel #1
Station 13+65
Reference Head Elevation 1415.43
Zero is initial reading



HARLAN DIVERSION PROJECT
OBSERVATION WELL(C-204)
ELEVATION
DATE
TOR ELEV
WATER ELEV
RIV ST ELEV

PLATE I-23

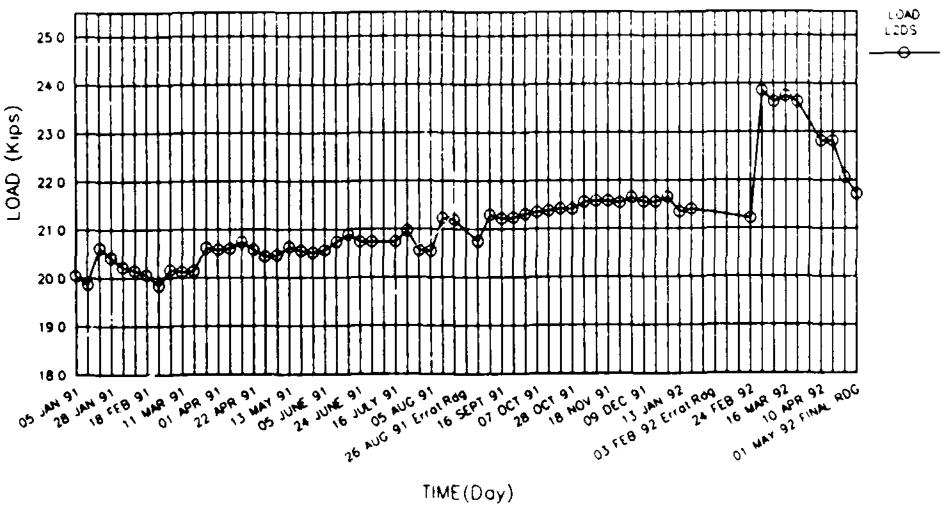
HARLA' DIVERSION PROJECT
LOAD _ELL (L1DS) READOUT GRAPH



Load Cell L1DS Installed 7/12/90
Location Sta 10+36.1 / Offset 51.1' Rt ("B")
Elevation 1189.36'

01 MAY 92 NO FURTHER MONITORING

HARLAN DIVERSION PROJECT
LOAD CELL (L2DS) READOUT GRAPH

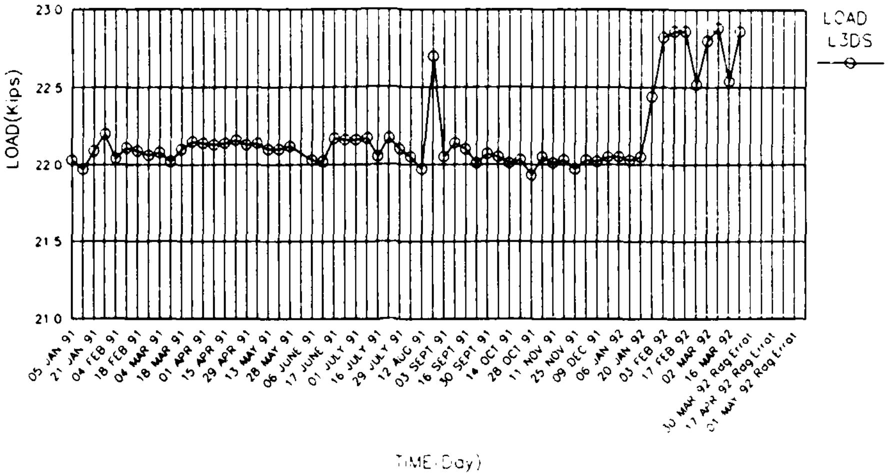


Load Cell L2DS Installed 7/12/90
Location Sta 10+92.6 / Offset 17.3' Rt ("B")
Elevation 1189.42

01 MAY 92 NO FURTHER MONITORING

PLATE I-24

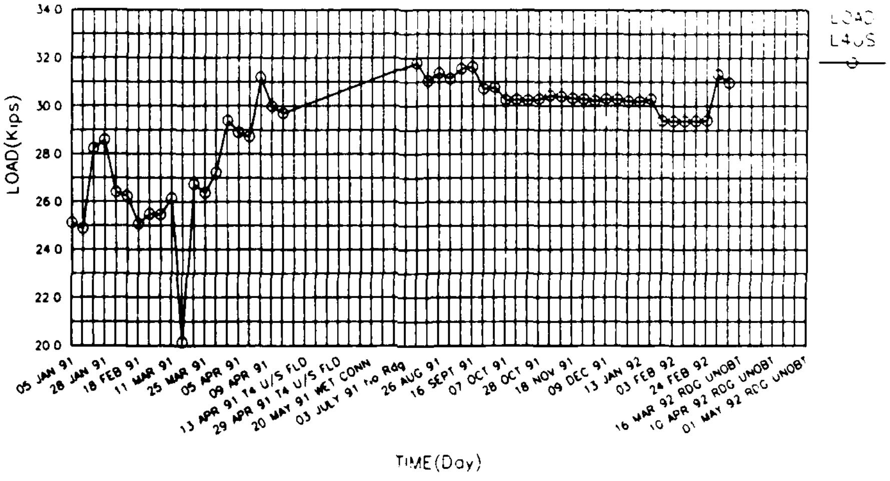
HARLAN DIVERSION PROJECT
LOAD CELL (L3DS) READOUT GRAPH



Load Cell L3DS Installed 8/14/90
Location Sta 10+87.3 / Offset 16.8'Rt BL("B")
Elevation 1169.56

01 MAY 92 NO FURTHER MONITORING

HARLAN DIVERSION PROJECT
LOAD CELL (L4US) READOUT GRAPH

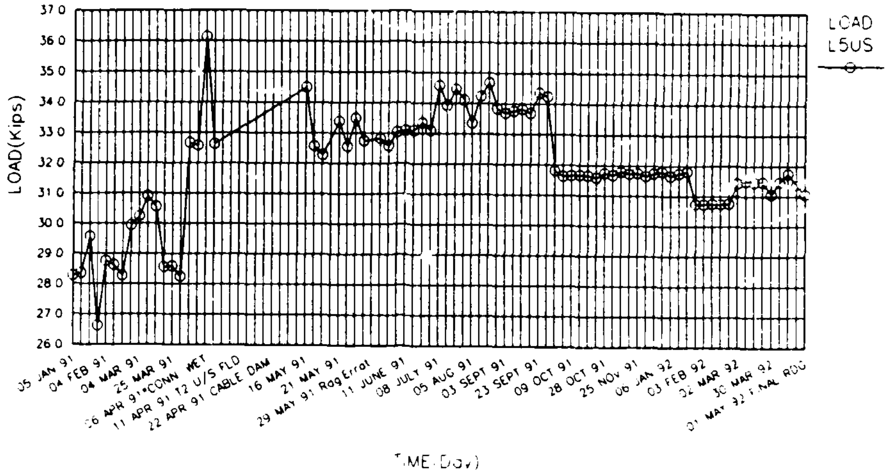


Load Cell L4US Installed 8/27/90
Location BL"B" 30+13 /Offset 78.8'Rt of BL("B")
Elevation 1234.0

01 MAY 92 NO FURTHER MONITORING

HARLAN DIVERSION PROJECT

LOAD CELL (L5US) READOUT GRAPH



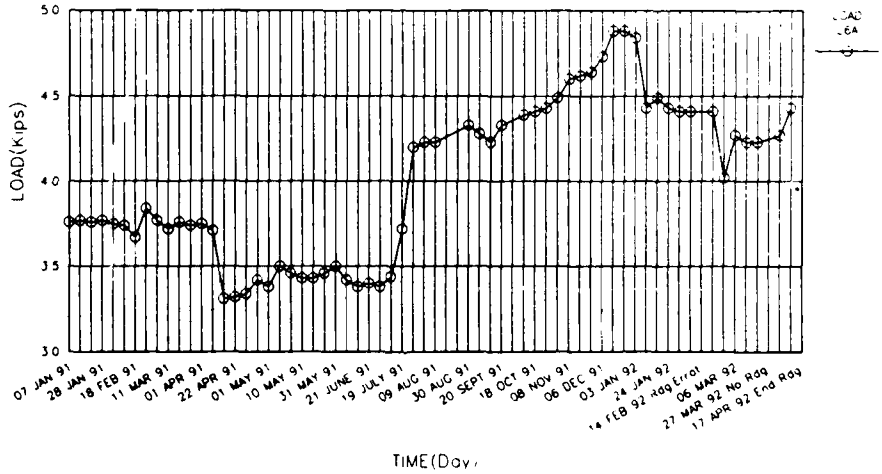
Load cell L5US
Location 2+3?.?
Elevation ?.?6.5

Installed 9/19/90
Offset cell BL 18

01 MAY 92 NO FURTHER MONITORING

HARLAN DIVERSION PROJECT

LOAD CELL (L6A) READOUT GRAPH



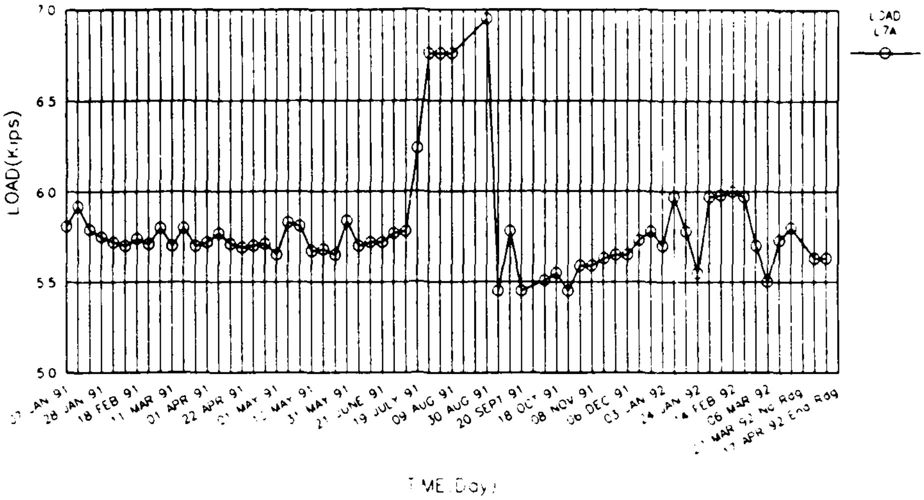
Load cell L6A
Location Crown
Elevation 1188.2

Installed 9/26/90
Station 10+75

Tunnel ... Array A
01 MAY 92 NO FURTHER MONITORING

HARLAN DIVERSION PROJECT

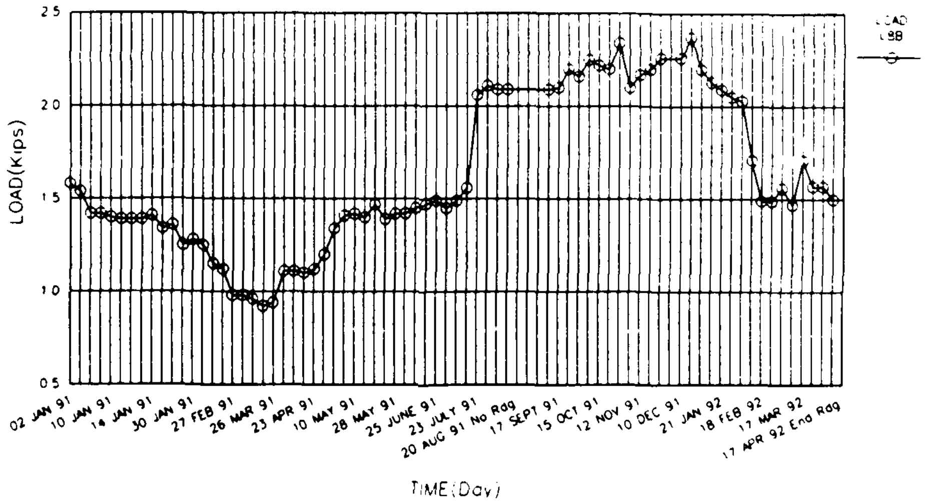
LOAD CELL (L7A) READOUT GRAPH



Load cell L7A
Location Right Bauch
Installed 9/26/90
Station 10+76.5

HARLAN DIVERSION PROJECT

LOAD CELL (8B) READOUT GRAPH

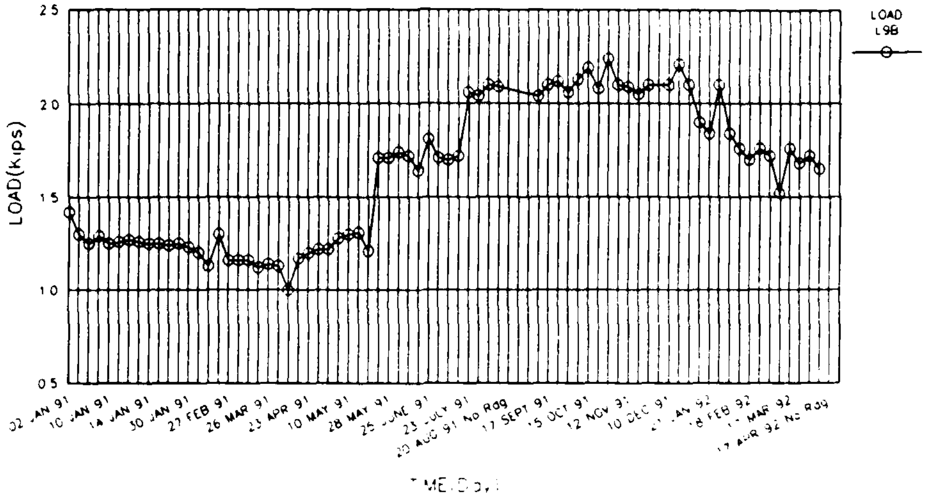


Load cell L8B
Location Crown Array 8"
Elevation 1189.95
Installed 10/27/90
Station 13+65-67
Tunnel T-1 Array B

PLATE I-27

HARLAN, KENTUCKY
SPB EXTENSOMETERS, T1

HARLAN DIVERSION PROJECT
LOAD CELL (L9B) READOUT GRAPH

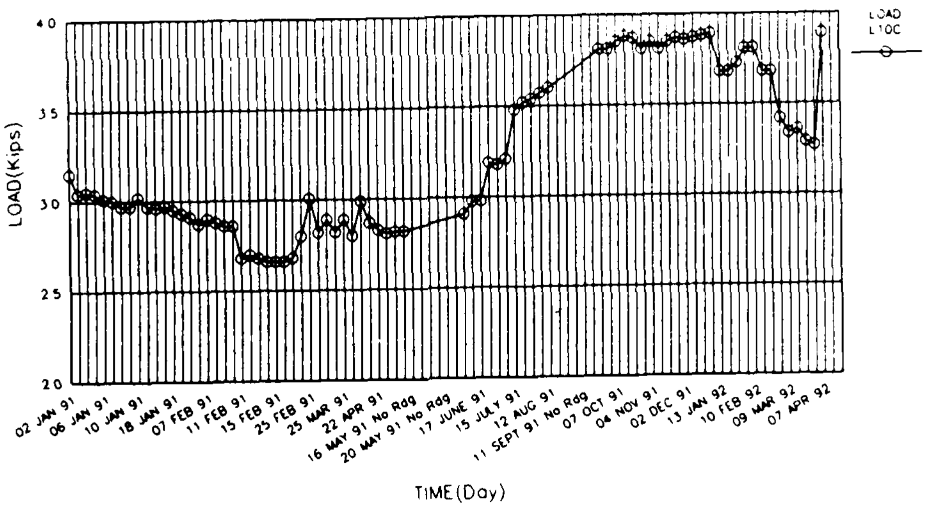


Load cell L9B
Location Right Bauch
Elevation 1180.95

Installed 10/27/90
Station 13+67

01 MAY 92 NO FURTHER MONITORIN

HARLAN DIVERSION PROJECT
LOAD CELL (L10C) READOUT GRAPH



Load Cell L10C
Location Crown C
Elevation 1191.37

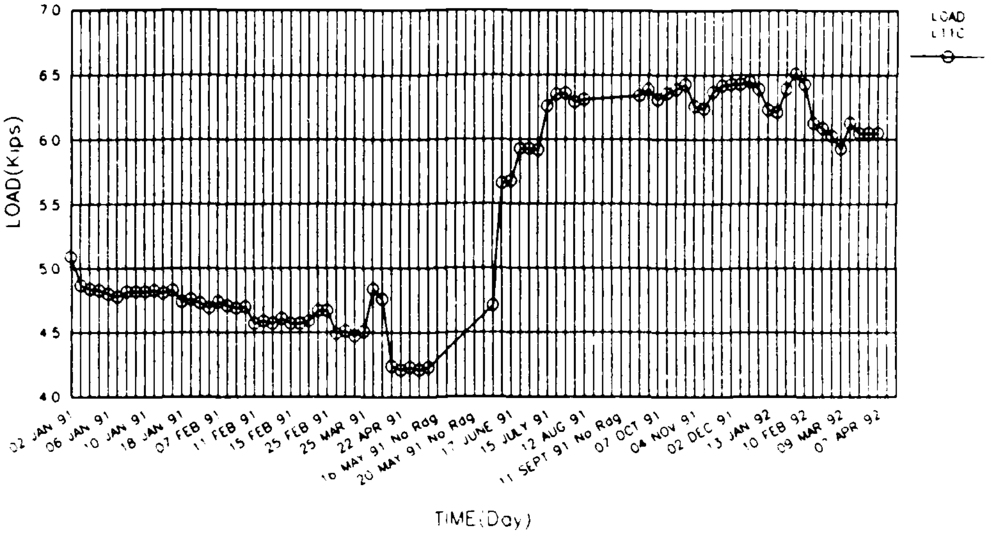
Installed 11/14/90
Station 15+98

Tunnel T-1 Array
01 MAY 92 NO FURTHER MONITORIN

PLATE I-28

HARLAN, KENTUCKY

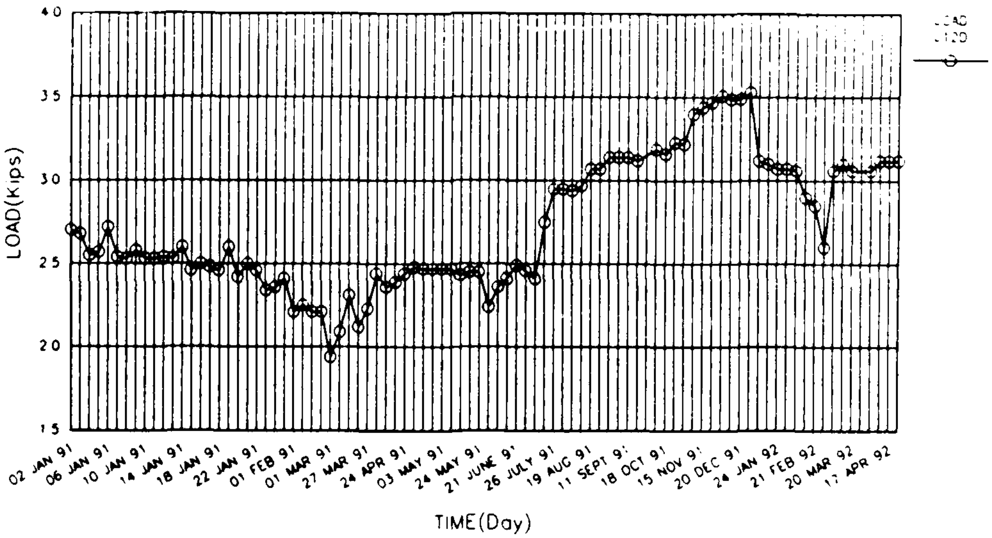
HARLAN DIVERSION PROJECT
LOAD CELL (L11C) READOUT GRAPH



Load Cell L11C Installed 11/14/90
Location Rt. Haunch Station 15+98
Elevation 1182.37

Tunnel T-1 Array
01 MAY 92 NO FURTHER MONITORING

HARLAN DIVERSION PROJECT
LOAD CELL (L12D) READOUT GRAPH

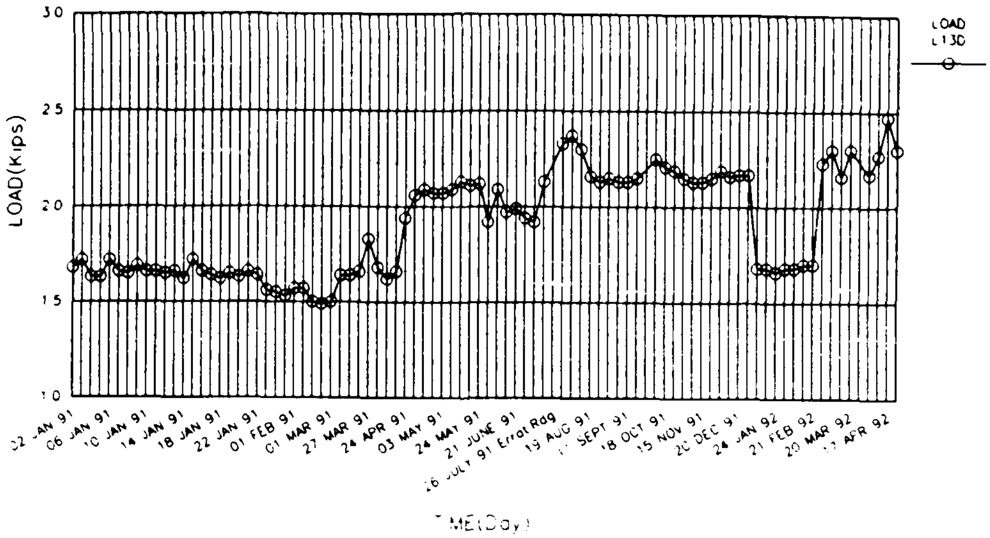


Load cell L12D Installed 11/27/90
Location Crown Station 11+26
Elevation 1188.47

Tunnel T-2 Array
01 MAY 92 NO FURTHER MONITORING

PLATE I-29

HARLAN DIVERSION PROJECT
LOAD CELL (L13D) READOUT GRAPH

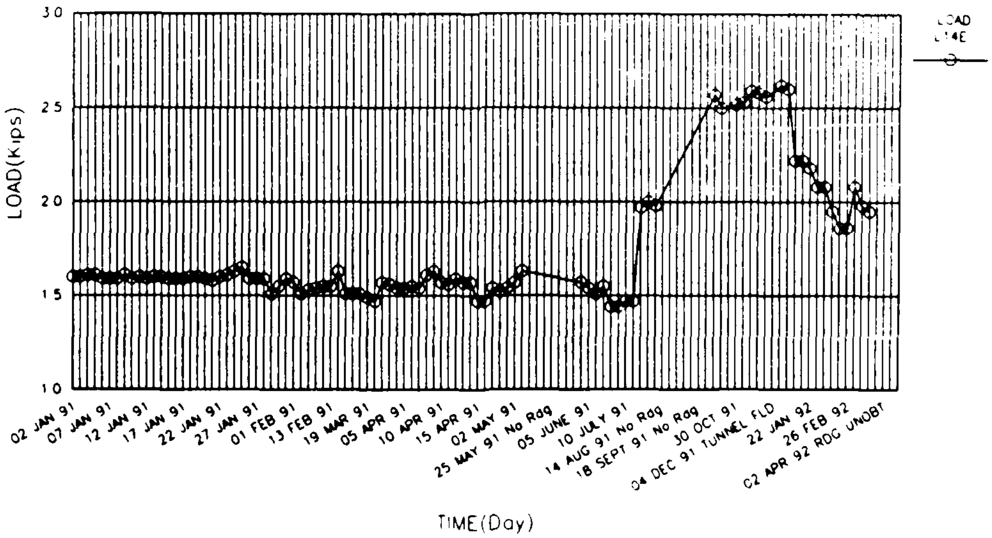


Load Cell L13D
Location Rt. Haunch
Elevation [illegible]

Installed [illegible]
Station [illegible]

Tunnel T-2 Array D
[illegible] MAY 92 NO FURTHER MONITORING

HARLAN DIVERSION PROJECT
LOAD CELL (L14E) READOUT GRAPH



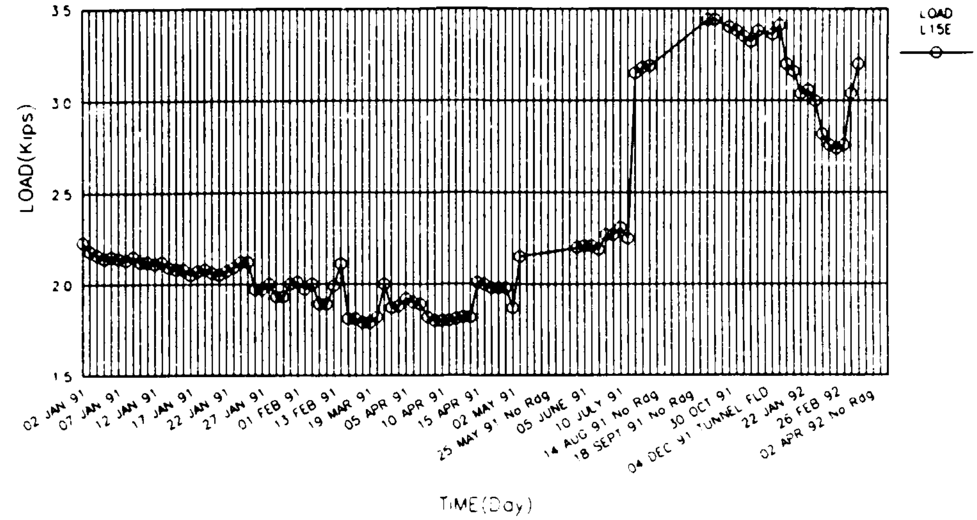
Load Cell L14E
Location Crown
Elevation 1193.03

Installed 12/06/90
Station 18+68

Tunnel T-1 Array E
01 MAY 92 NO FURTHER MONITORING

PLATE I-30

HARLAN DIVERSION PROJECT
LOAD CELL (L15E) READOUT GRAPH

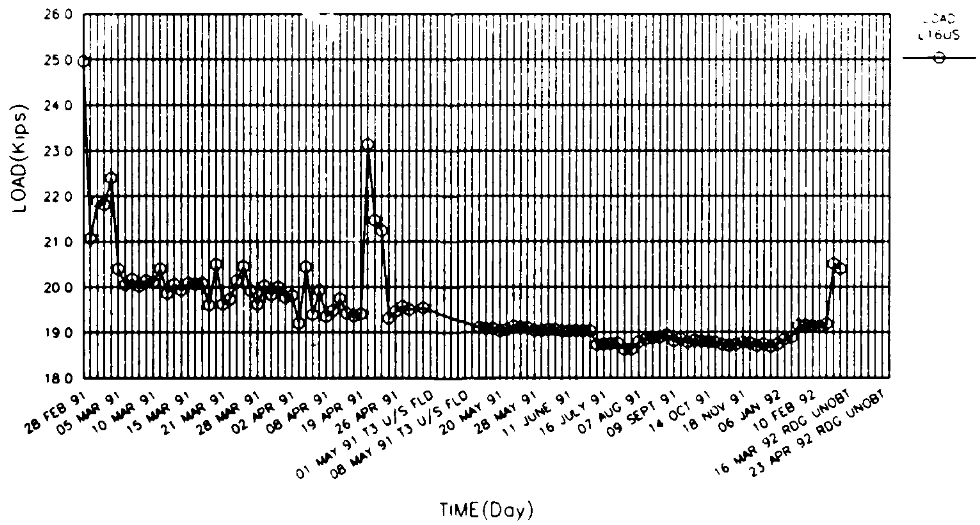


Load Cell L15E
Location Rt. Haunch
Elevation 1184.03

Installed 12.06.90
Station 18+68

Tunnel T-1 Array E
01 MAY 92 NO FURTHER MONITORING

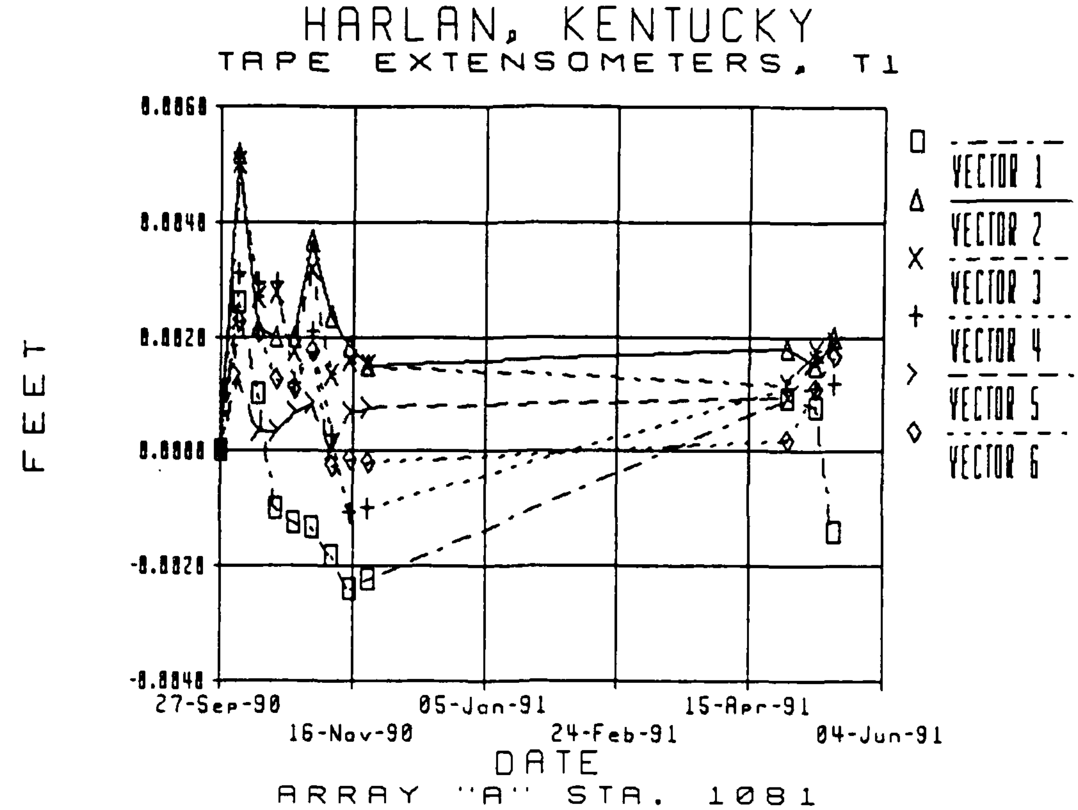
HARLAN DIVERSION PROJECT
LOAD CELL (L16US) READOUT GRAPH



Load Cell L16US
Location Sta. 30+20, 10' Lt. of rt. Wall of T-3
Elevation 1210.10

Installed 28 FEB 91

01 MAY 92 NO FURTHER MONITORING


HARLAN, KENTUCKY
TAPE EXTENSOMETERS, T1
0.0060
0.0040
0.0020
0.0000
-0.0020
-0.0040
FEET
27-Sep-90
16-Nov-90
05-Jan-91
24-Feb-91
15-Apr-91
04-Jun-91
DATE
ARRAY "A" STA. 1081
VECTOR 1
VECTOR 2
VECTOR 3
VECTOR 4
VECTOR 5
VECTOR 6

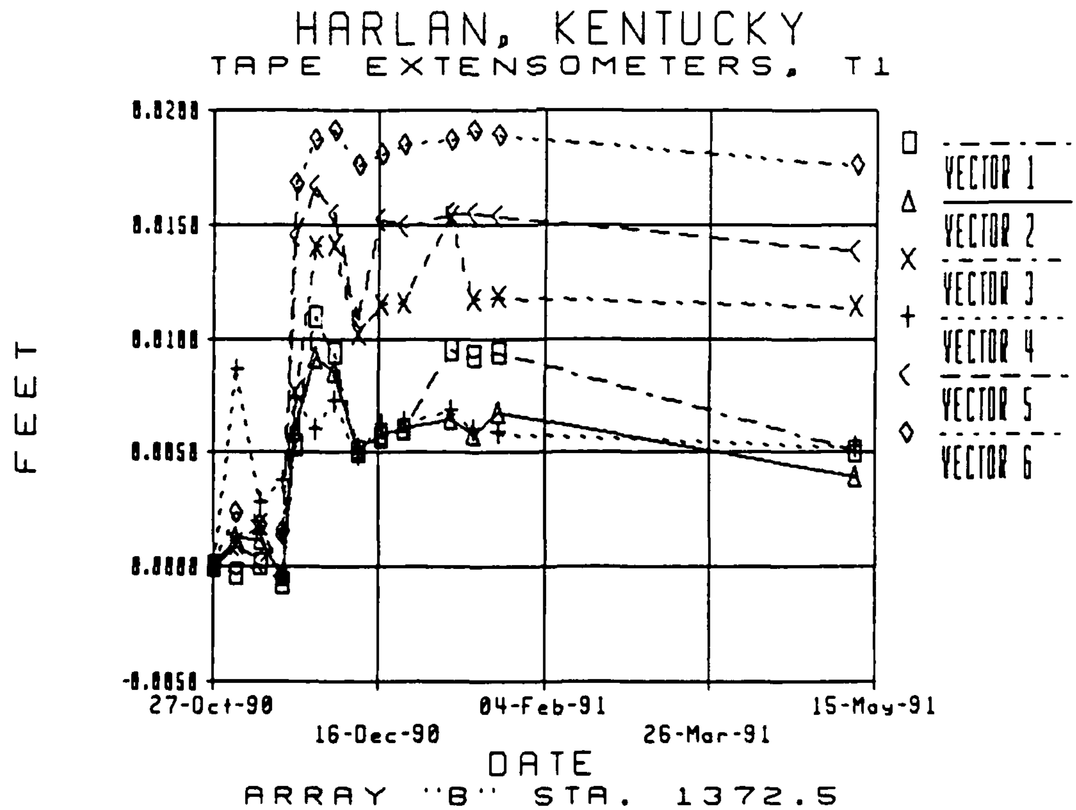
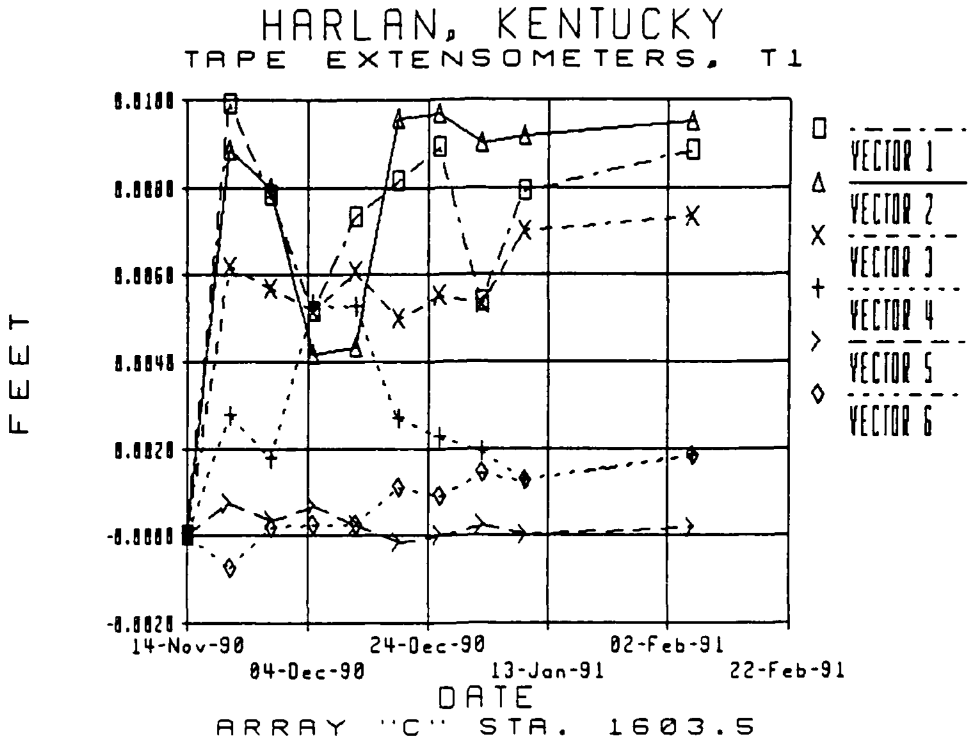

HARLAN, KENTUCKY
TAPE EXTENSOMETERS, T1
0.0200
0.0150
0.0100
0.0050
0.0000
-0.0050
FEET
27-Oct-90
16-Dec-90
04-Feb-91
26-Mar-91
15-May-91
DATE
ARRAY "B" STA. 1372.5
VECTOR 1
VECTOR 2
VECTOR 3
VECTOR 4
VECTOR 5
VECTOR 6

PLATE I-32



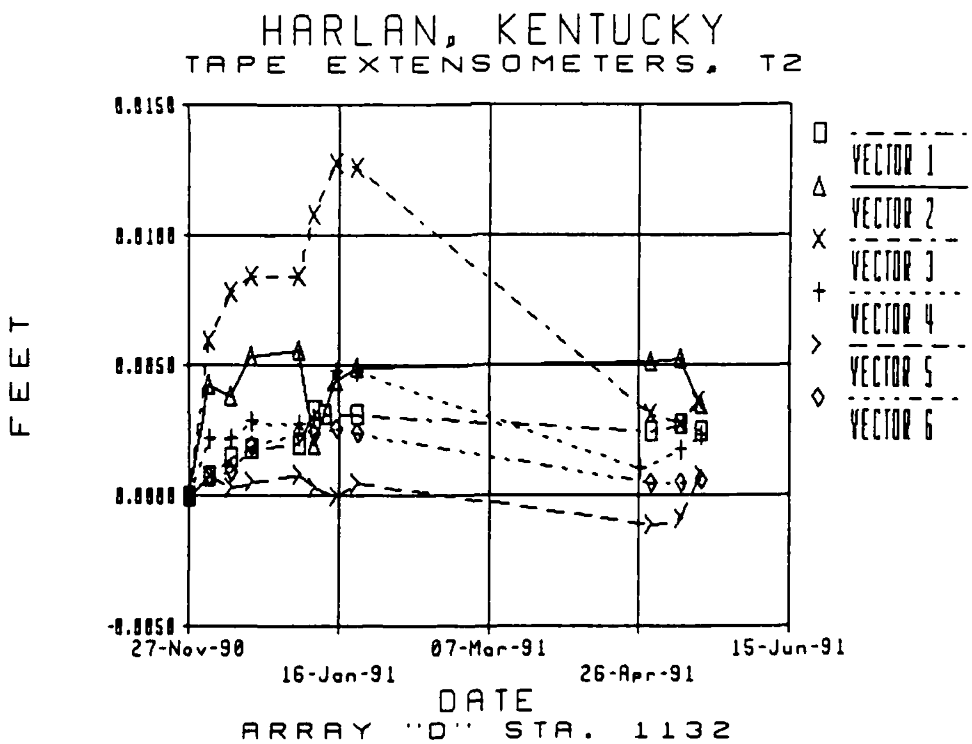
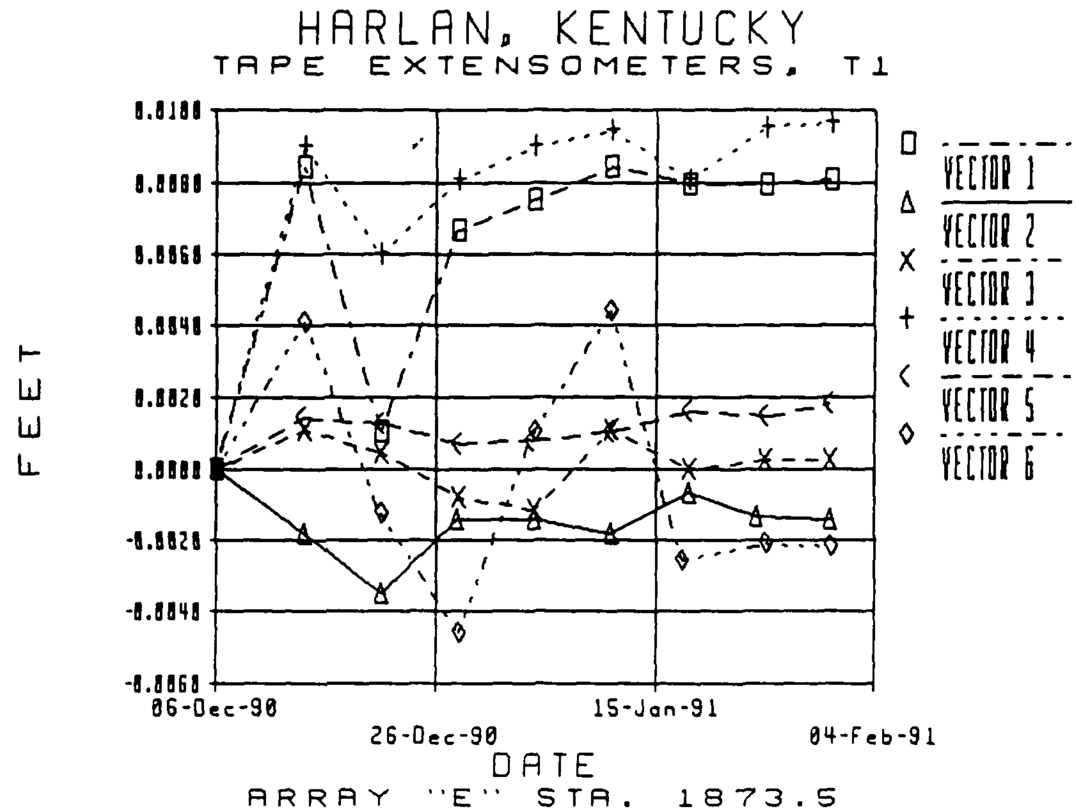


PLATE I-33

HARLAN, KENTUCKY


HARLAN, KENTUCKY
TAPE EXTENSOMETERS, T1
FEET
0.0100
0.0080
0.0060
0.0040
0.0020
0.0000
-0.0020
-0.0040
-0.0060
06-Dec-90
26-Dec-90
15-Jan-91
04-Feb-91
DATE
ARRAY "E" STA. 1873.5
VECTOR 1
VECTOR 2
VECTOR 3
VECTOR 4
VECTOR 5
VECTOR 6

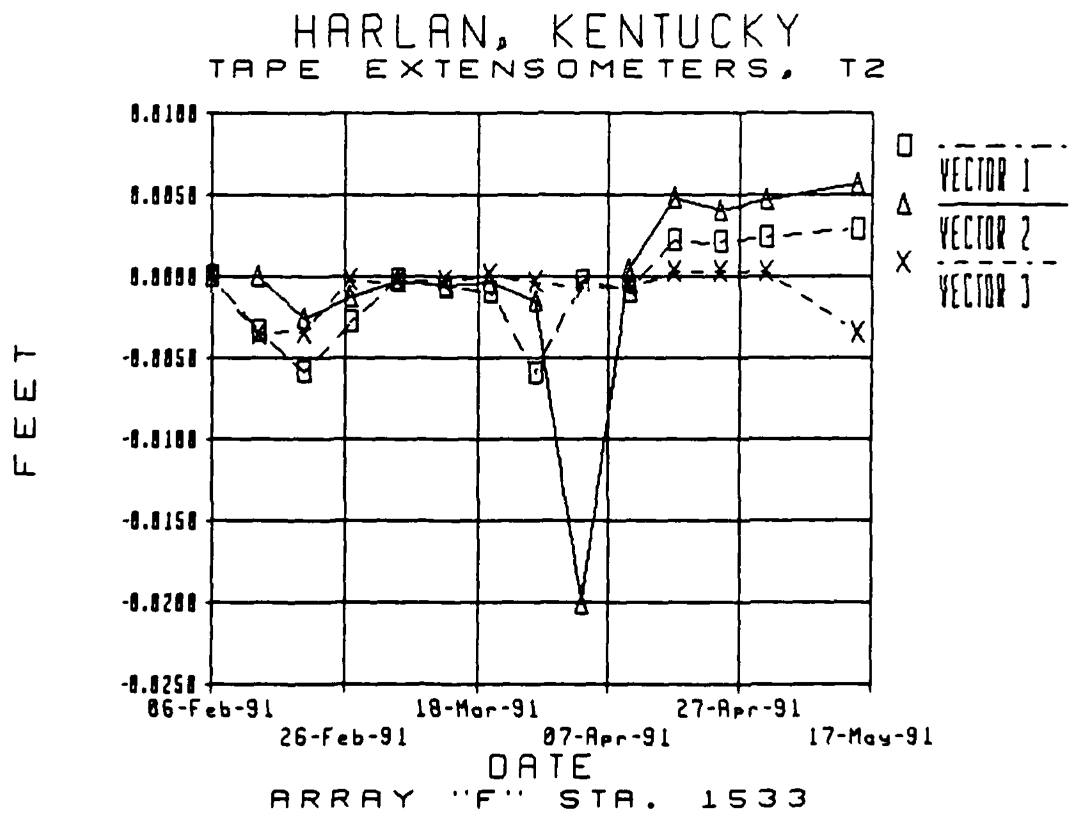
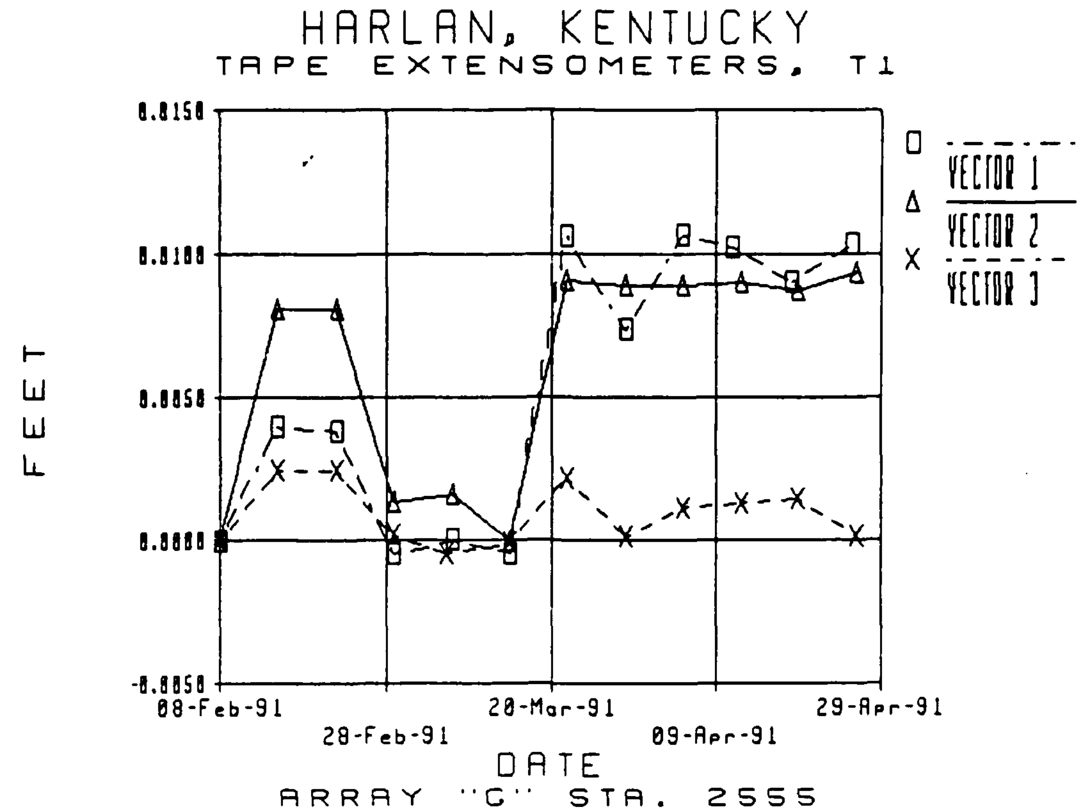

HARLAN, KENTUCKY
TAPE EXTENSOMETERS, T2
FEET
0.0100
0.0050
0.0000
-0.0050
-0.0100
-0.0150
-0.0200
-0.0250
06-Feb-91
26-Feb-91
18-Mar-91
07-Apr-91
27-Apr-91
17-May-91
DATE
ARRAY "F" STA. 1533
VECTOR 1
VECTOR 2
VECTOR 3

PLATE I-34


HARLAN, KENTUCKY
TAPE EXTENSOMETERS, T1
0.0150
0.0100
0.0050
0.0000
-0.0050
FEET
08-Feb-91
28-Feb-91
20-Mar-91
09-Apr-91
29-Apr-91
DATE
ARRAY "G" STA. 2555
VECTOR 1
VECTOR 2
VECTOR 3

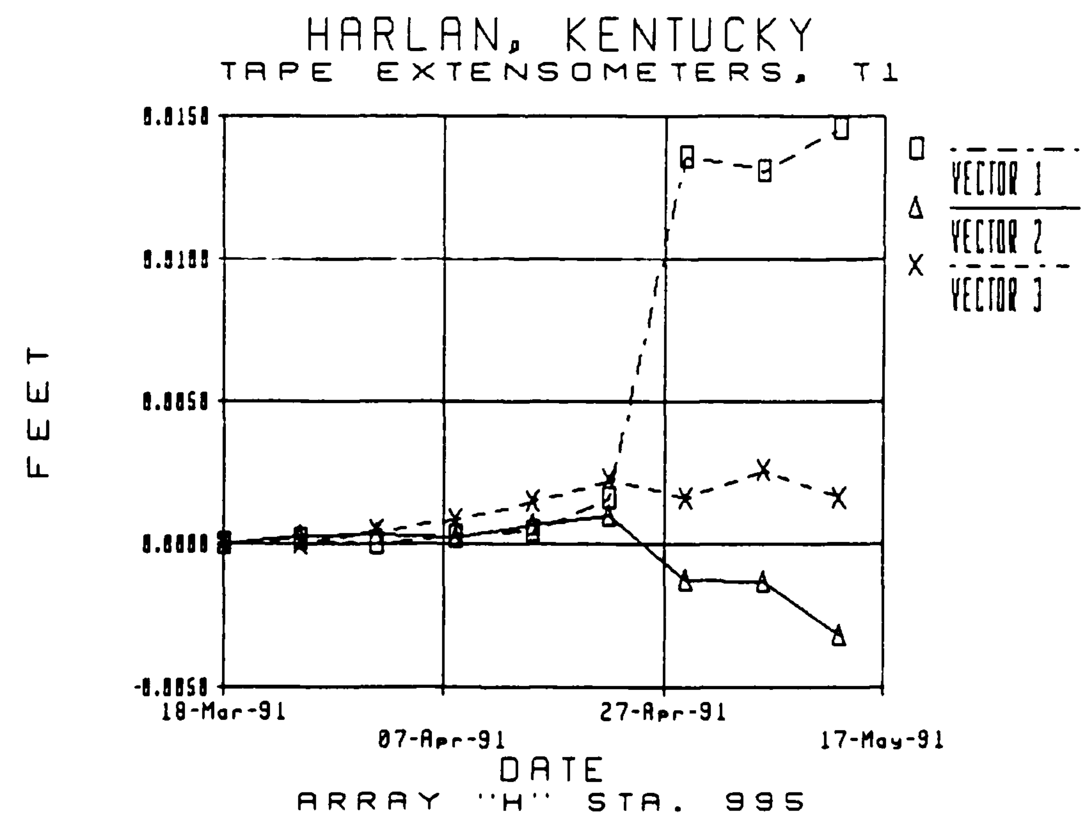
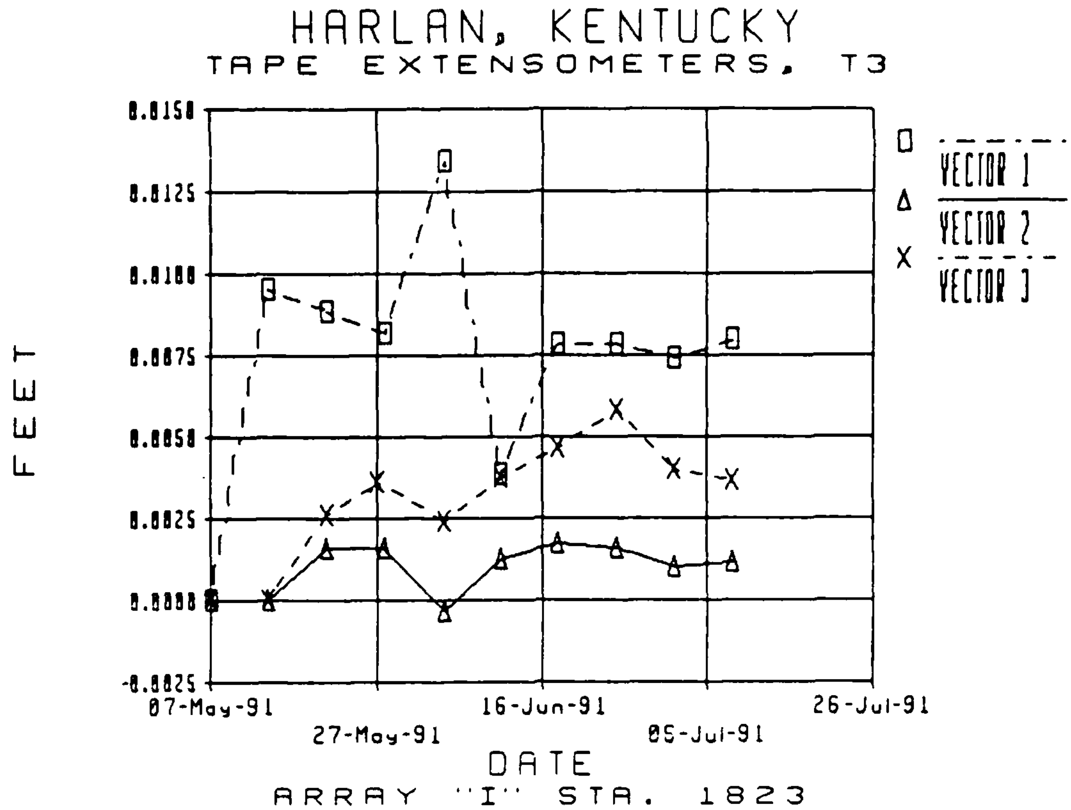
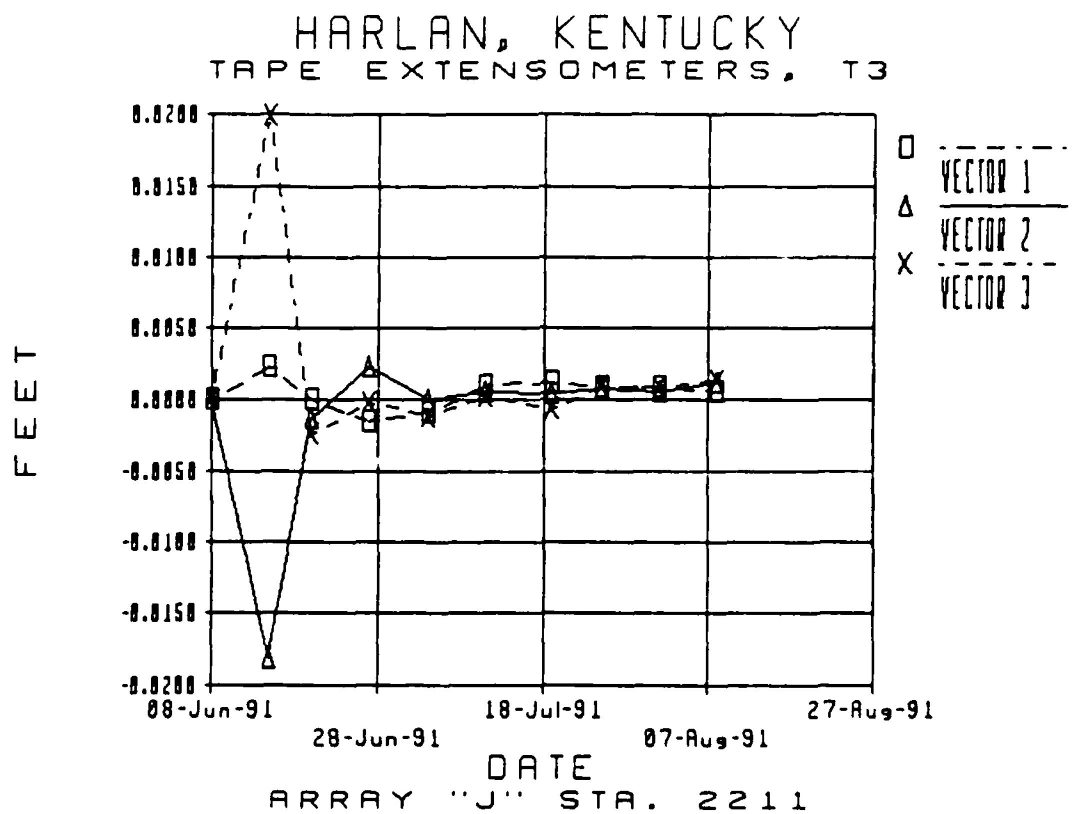

HARLAN, KENTUCKY
TAPE EXTENSOMETERS, T1
0.0150
0.0100
0.0050
0.0000
-0.0050
FEET
18-Mar-91
07-Apr-91
27-Apr-91
17-May-91
DATE
ARRAY "H" STA. 995
VECTOR 1
VECTOR 2
VECTOR 3

PLATE I-35

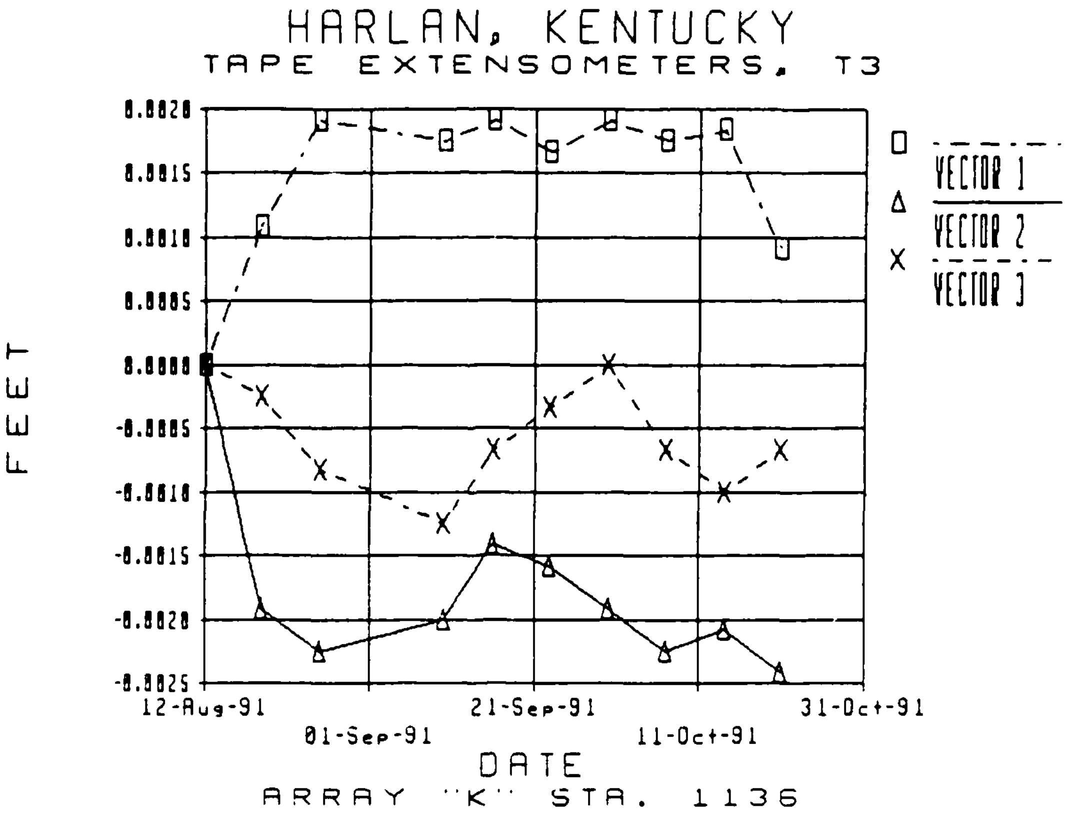


HARLAN, KENTUCKY
TAPE EXTENSOMETERS, T3
0.0150
0.0125
0.0100
0.0075
0.0050
0.0025
0.0000
-0.0025
VECTOR 1
VECTOR 2
VECTOR 3
FEET
07-May-91
27-May-91
16-Jun-91
05-Jul-91
26-Jul-91
DATE
ARRAY "I" STA. 1823



HARLAN, KENTUCKY
TAPE EXTENSOMETERS, T3
0.0200
0.0150
0.0100
0.0050
0.0000
-0.0050
-0.0100
-0.0150
-0.0200
VECTOR 1
VECTOR 2
VECTOR 3
FEET
08-Jun-91
28-Jun-91
18-Jul-91
07-Aug-91
27-Aug-91
DATE
ARRAY "J" STA. 2211

PLATE I-36


HARLAN, KENTUCKY
TAPE EXTENSOMETERS, T3
FEET
DATE
12-Aug-91
01-Sep-91
21-Sep-91
11-Oct-91
31-Oct-91
VECTOR 1
VECTOR 2
VECTOR 3
ARRAY "K" STA. 1136

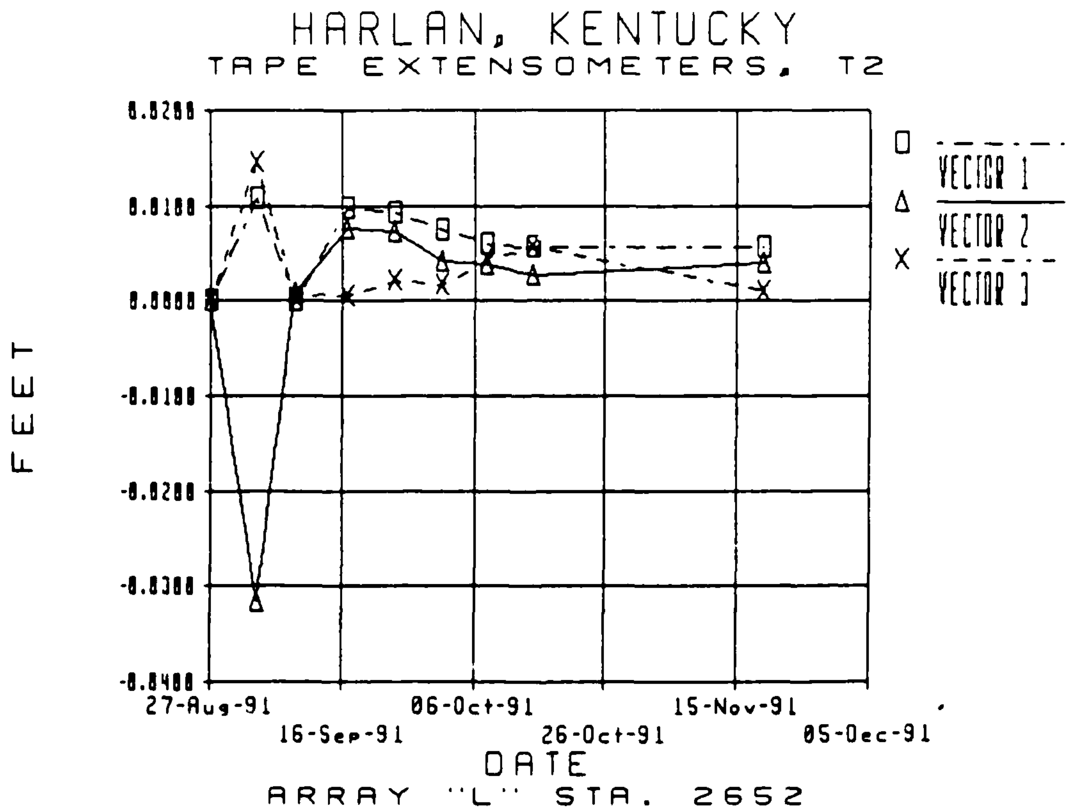
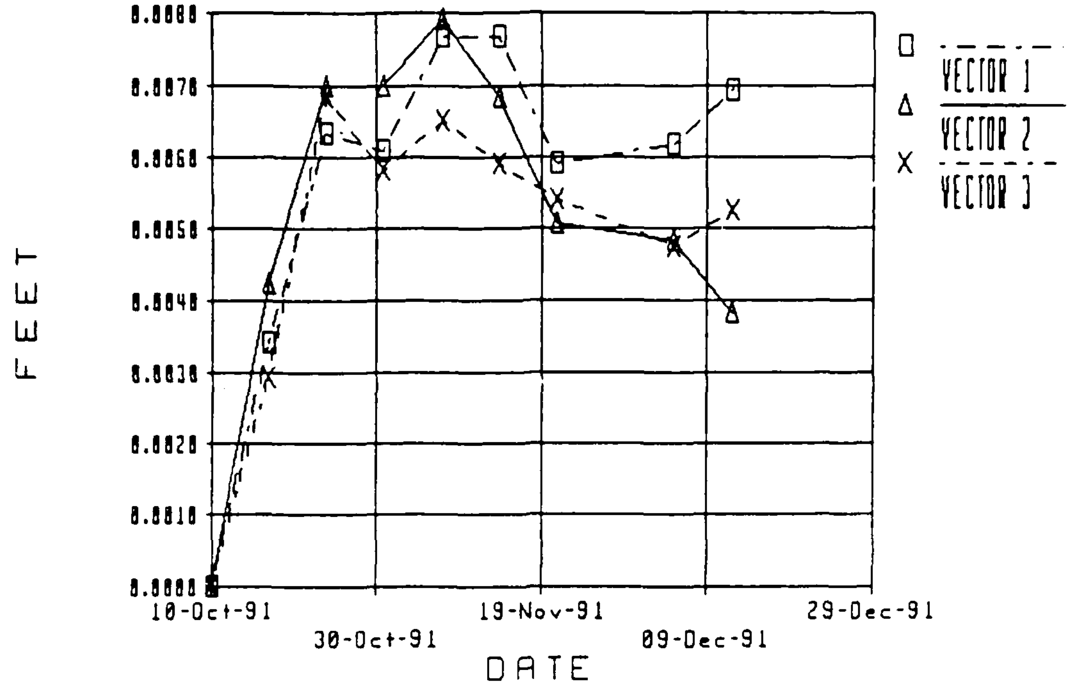

HARLAN, KENTUCKY
TAPE EXTENSOMETERS, T2
FEET
DATE
27-Aug-91
16-Sep-91
06-Oct-91
26-Oct-91
15-Nov-91
05-Dec-91
VECTOR 1
VECTOR 2
VECTOR 3
ARRAY "L" STA. 2652

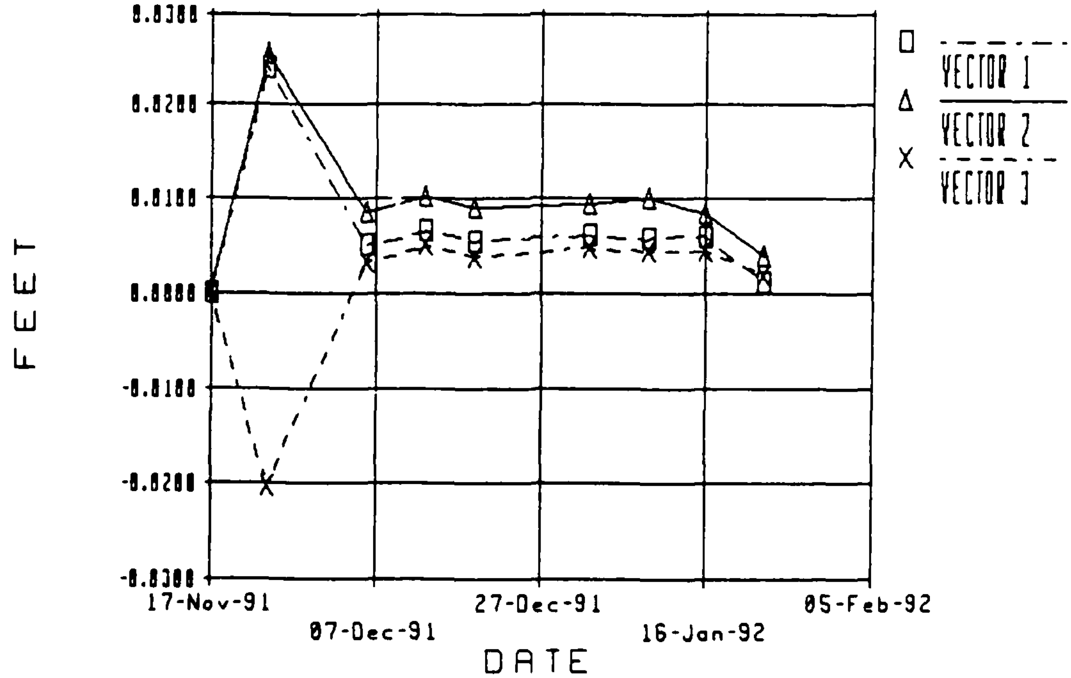
PLATE I-37

HARLAN, KENTUCKY
TAPE EXTENSOMETERS, T4



ARRAY "M" STA. 1382

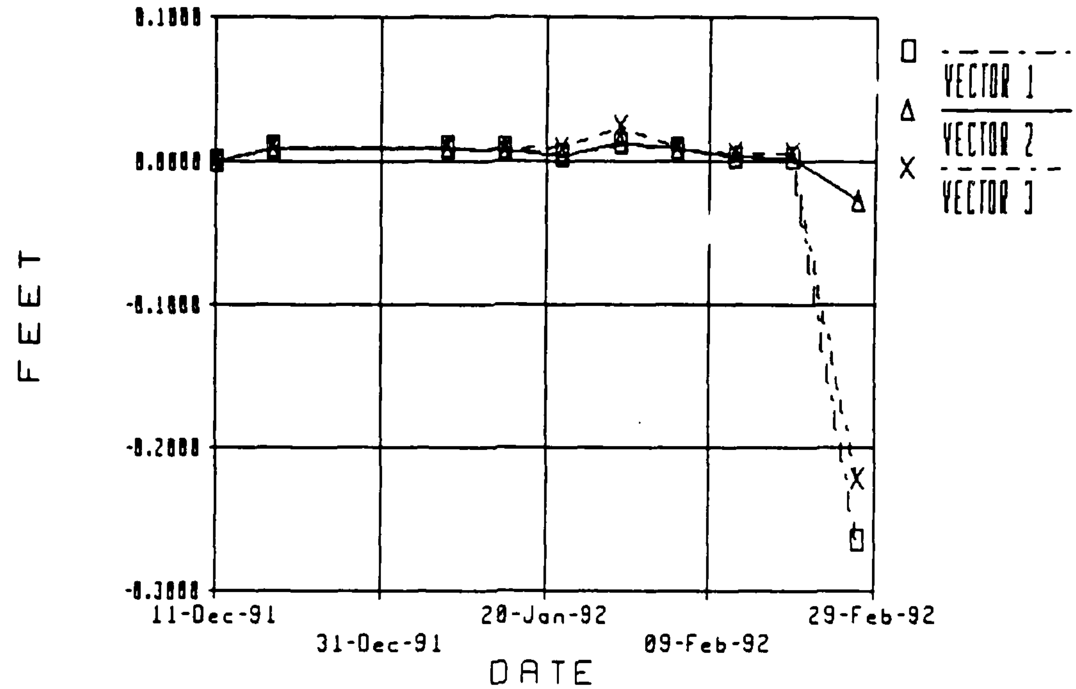
HARLAN, KENTUCKY
TAPE EXTENSOMETERS, T4



ARRAY "N" STA. 1597

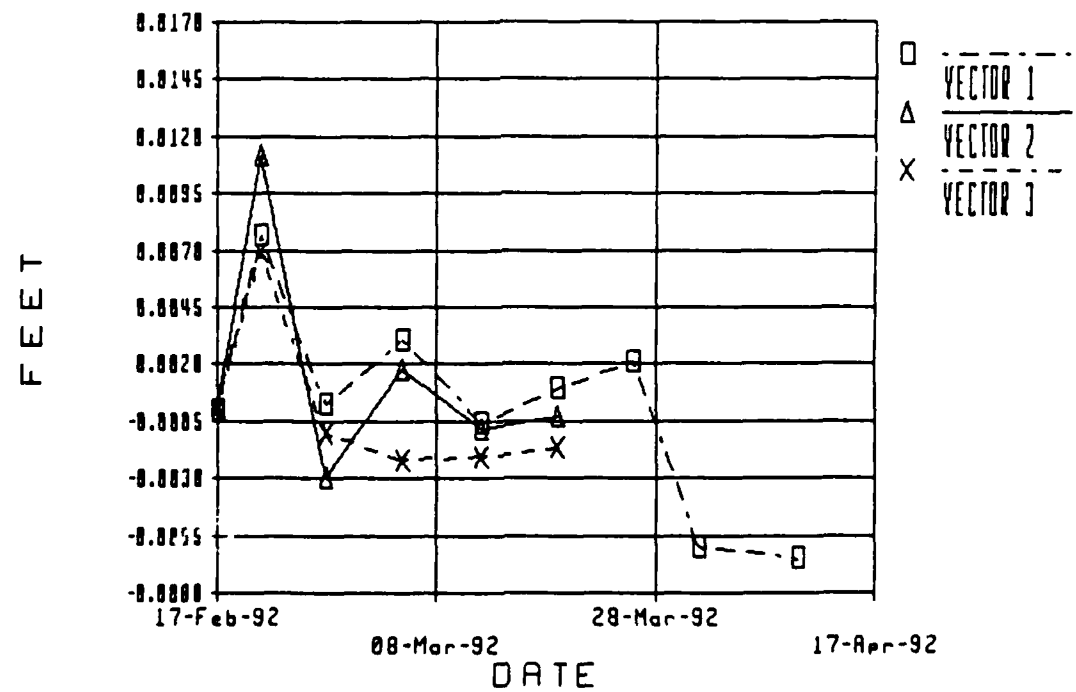
PLATE I-38

HARLAN, KENTUCKY
TAPE EXTENSOMETERS, T4



ARRAY "O" STA. 1923

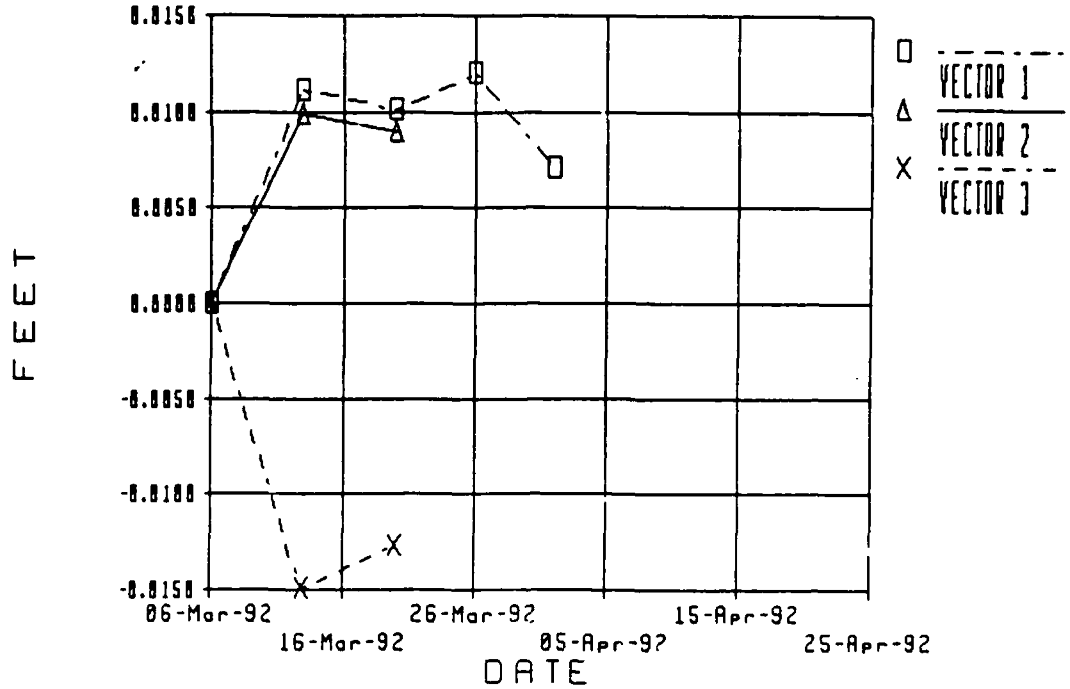
HARLAN, KENTUCKY
TAPE EXTENSOMETERS, T4



ARRAY "P" STA. 2396

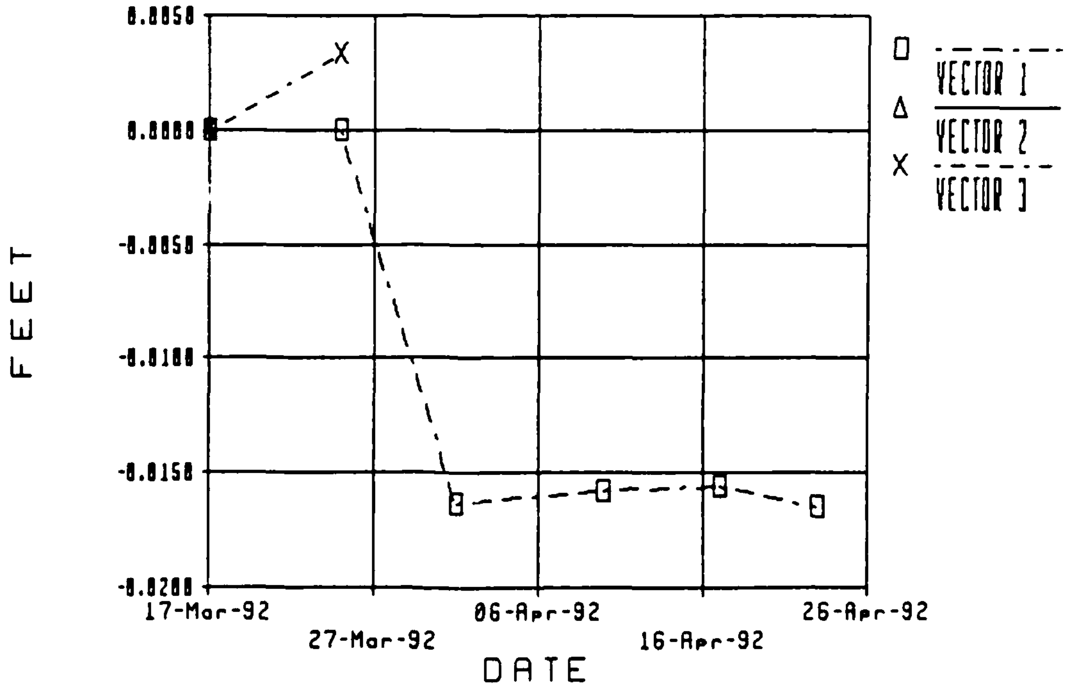
PLATE I-39

HARLAN, KENTUCKY
TAPE EXTENSOMETERS, T4



ARRAY "Q" STA. 2737

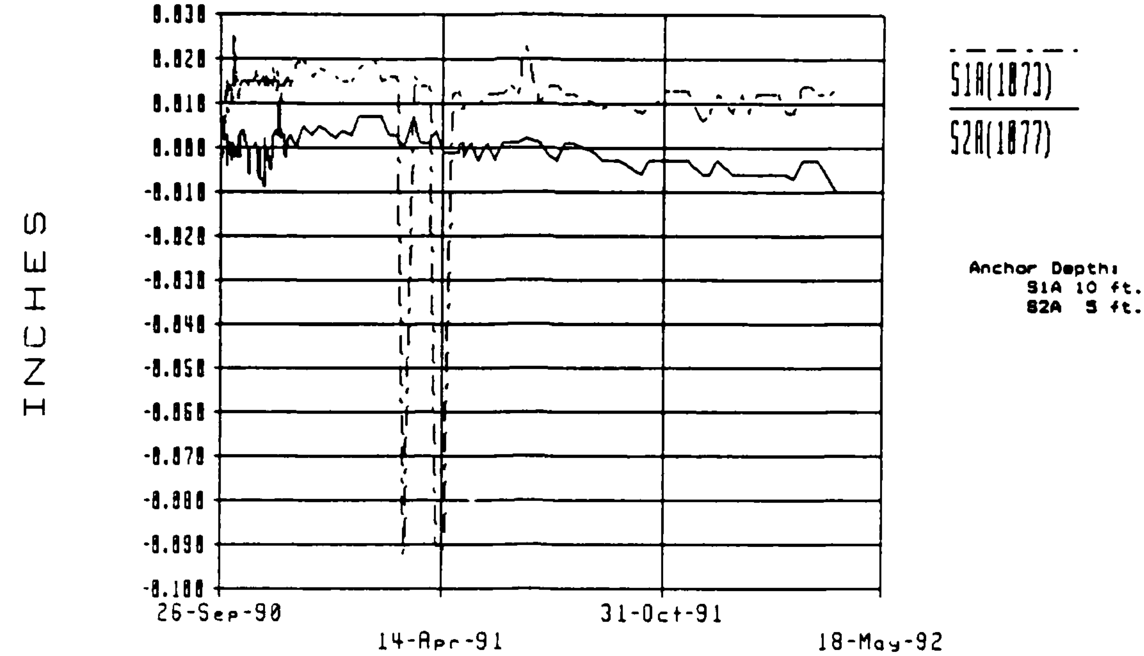
HARLAN, KENTUCKY
TAPE EXTENSOMETERS, T4



ARRAY "R" STA. 2905

PLATE I-40

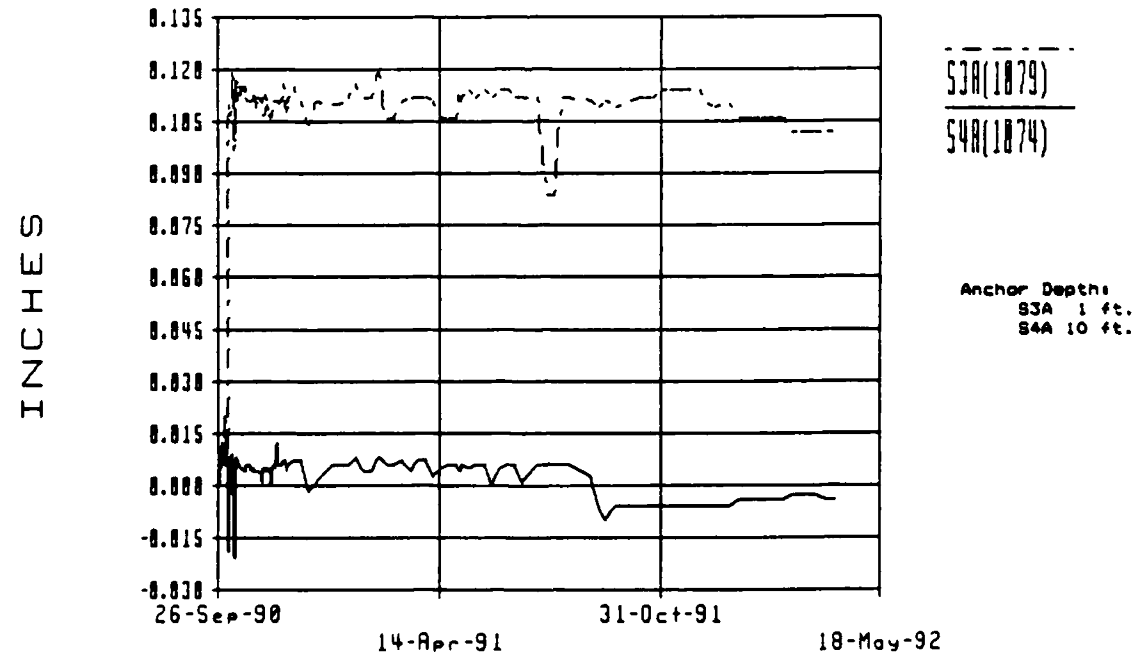
HARLAN, KENTUCKY
SPB EXTENSOMETERS, T1



DATE

ARRAY "A" STA. 1077

HARLAN, KENTUCKY
SPB EXTENSOMETERS, T1

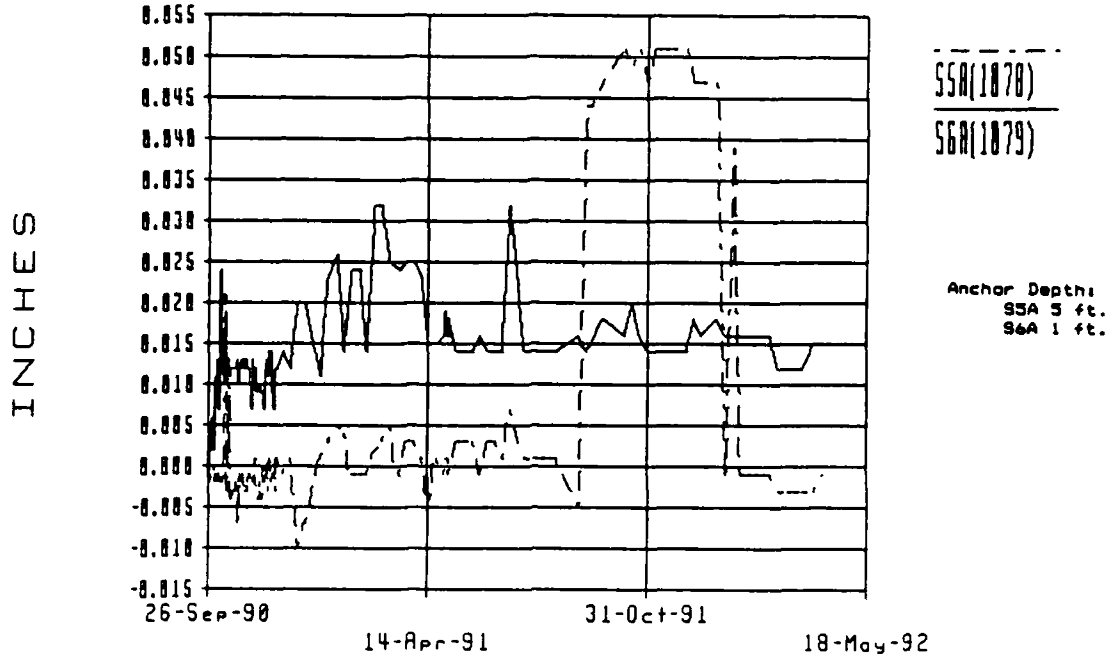


DATE

ARRAY "A" STA. 1077

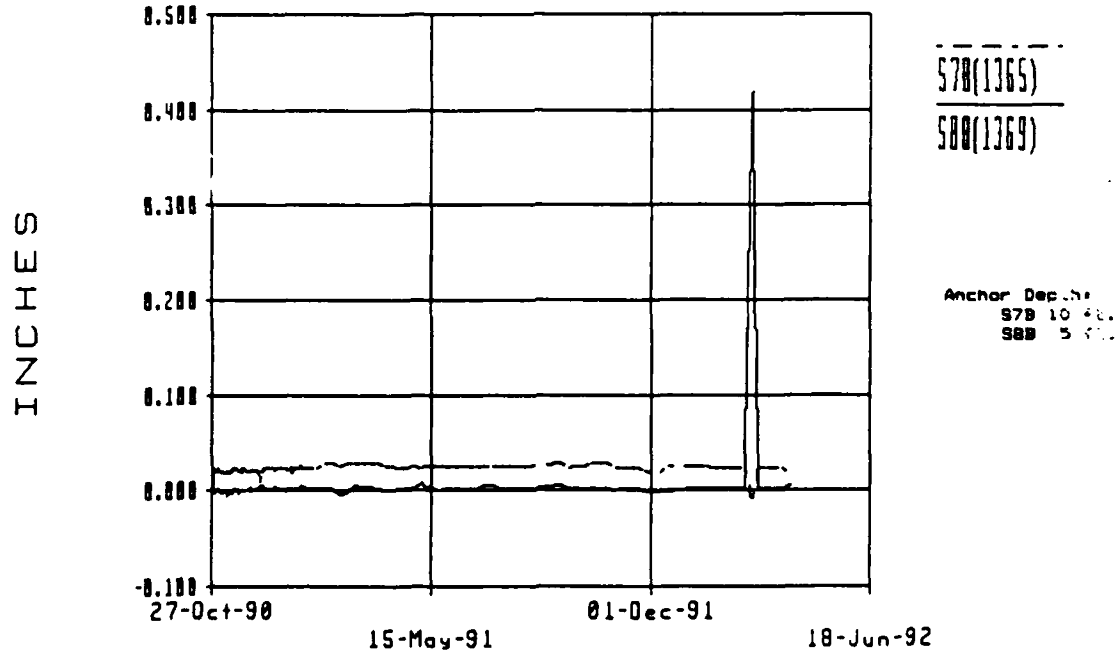
PLATE I-41

HARLAN, KENTUCKY
SPB EXTENSOMETERS, T1



ARRAY "A" STA. 1077

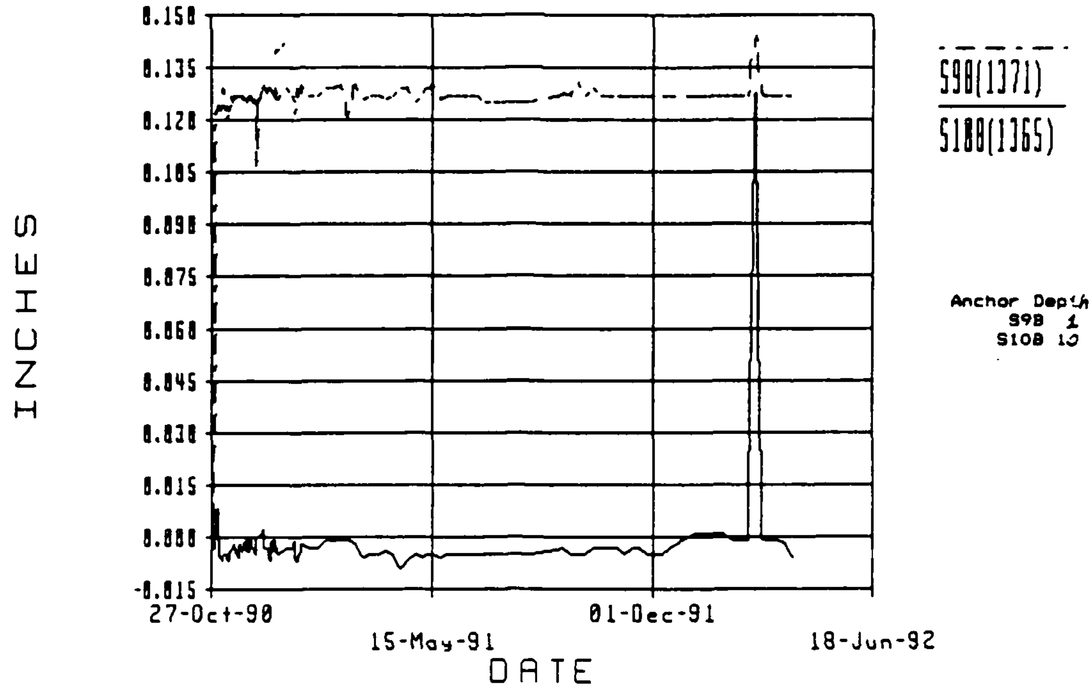
HARLAN, KENTUCKY
SPB EXTENSOMETERS, T1



ARRAY "B" STA. 1367

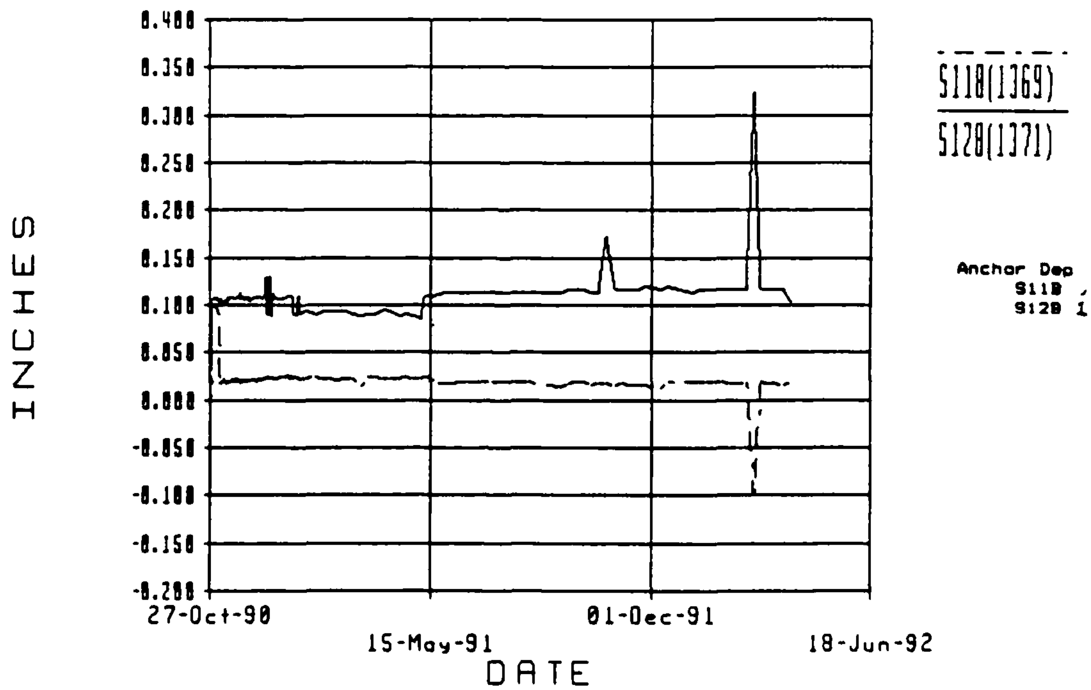
PLATE I-42

HARLAN, KENTUCKY
SPB EXTENSOMETERS, T1



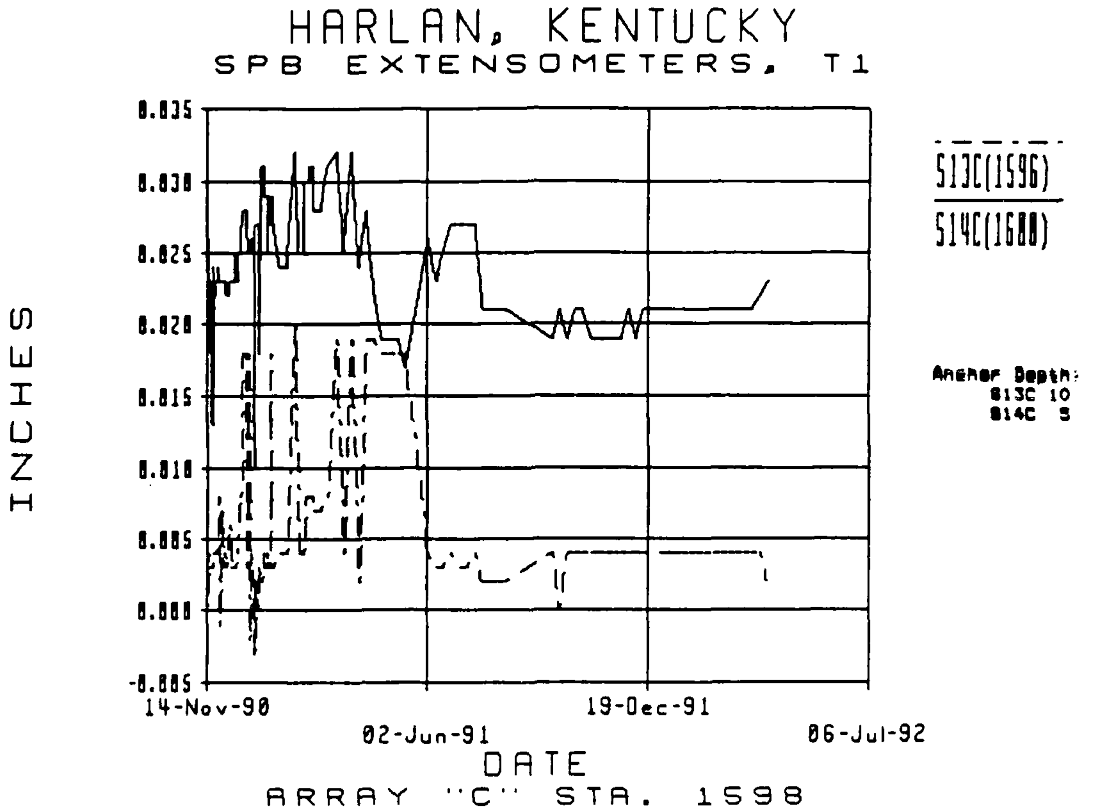
ARRAY "B" STA. 1367

HARLAN, KENTUCKY
SPB EXTENSOMETERS, T1



ARRAY "B" STA. 1367

PLATE I-43


HARLAN, KENTUCKY
SPB EXTENSOMETERS, T1
S13C(1596)
S14C(1600)
Anchor Depth:
S13C 10
S14C 5
INCHES
DATE
14-Nov-90
02-Jun-91
19-Dec-91
06-Jul-92
ARRAY "C" STA. 1598

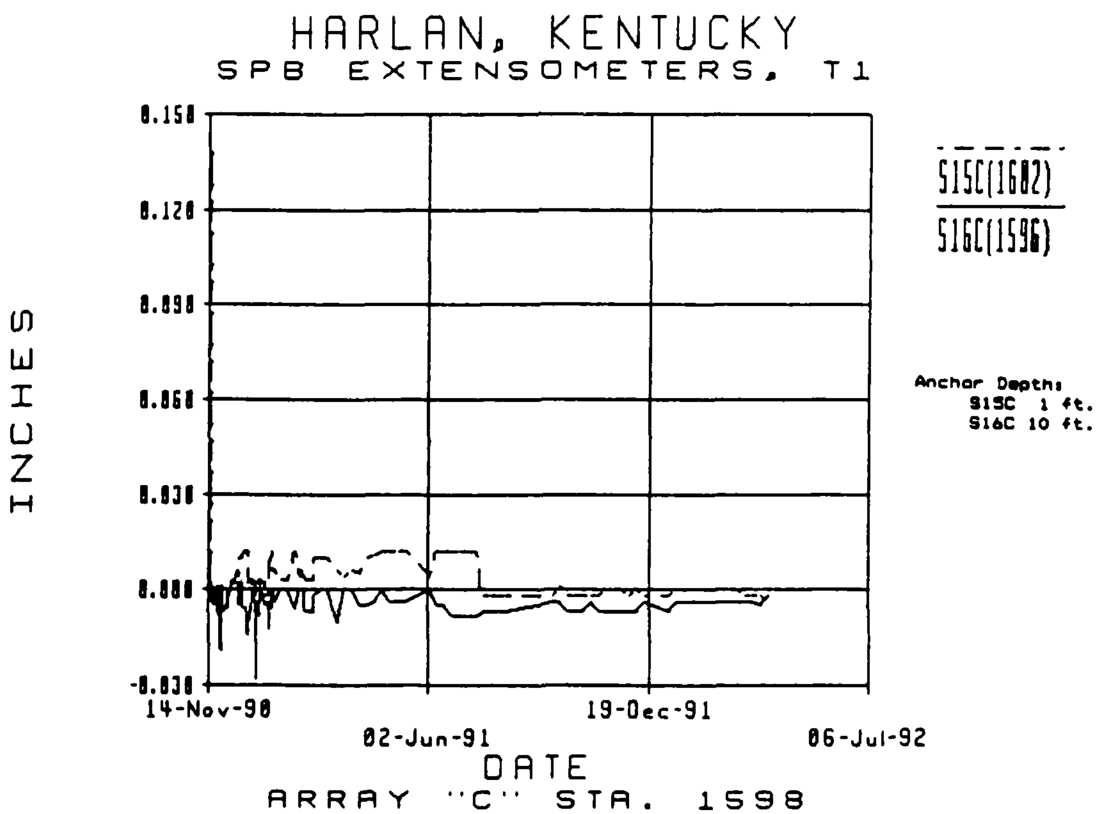
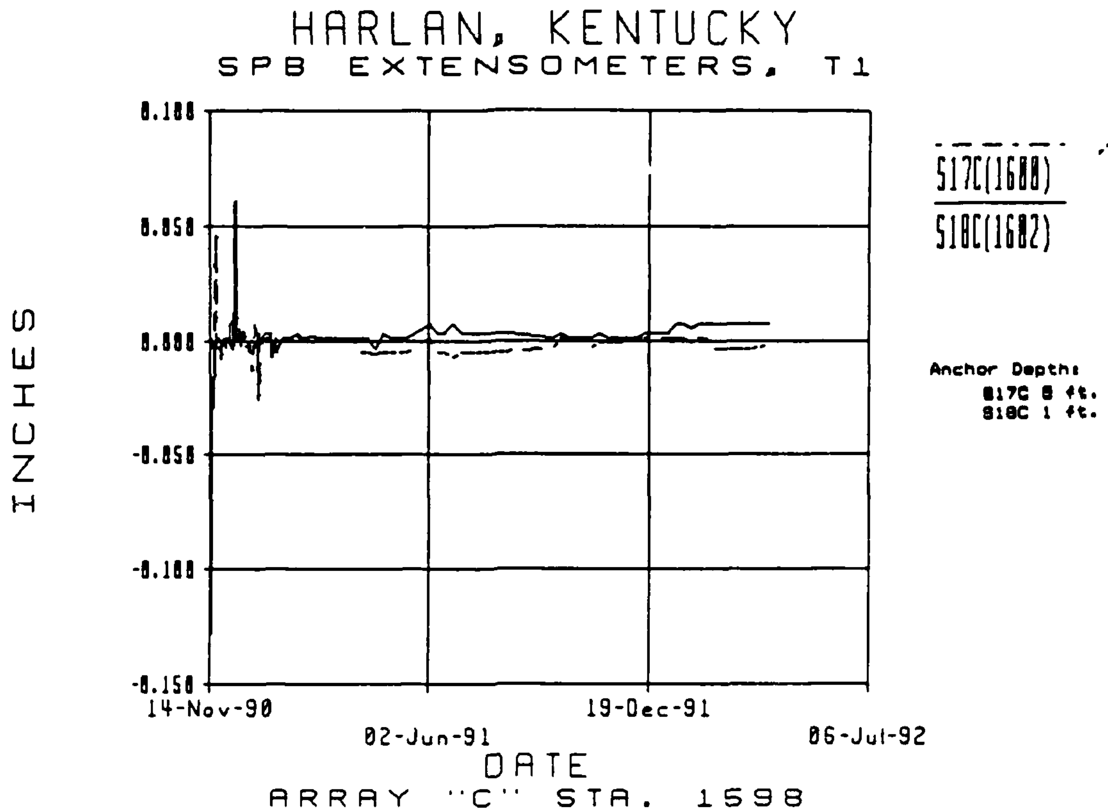
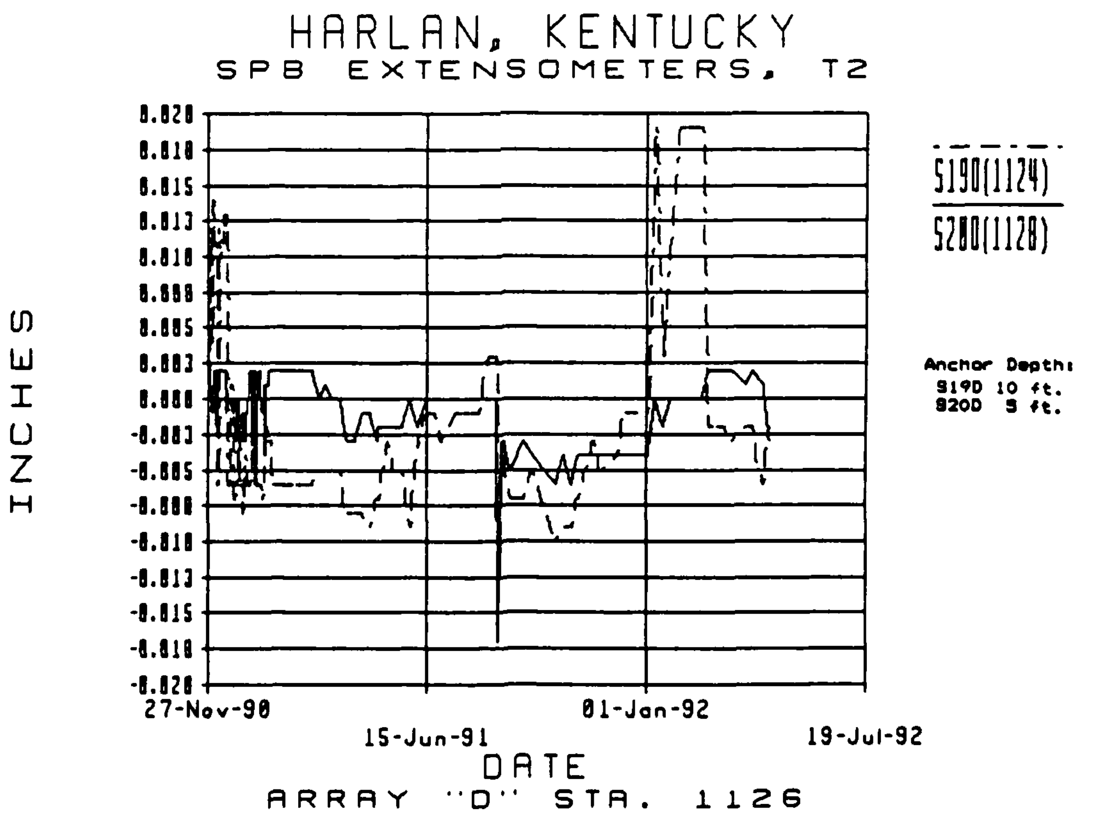

HARLAN, KENTUCKY
SPB EXTENSOMETERS, T1
S15C(1602)
S16C(1596)
Anchor Depth:
S15C 1 ft.
S16C 10 ft.
INCHES
DATE
14-Nov-90
02-Jun-91
19-Dec-91
06-Jul-92
ARRAY "C" STA. 1598

PLATE I-44

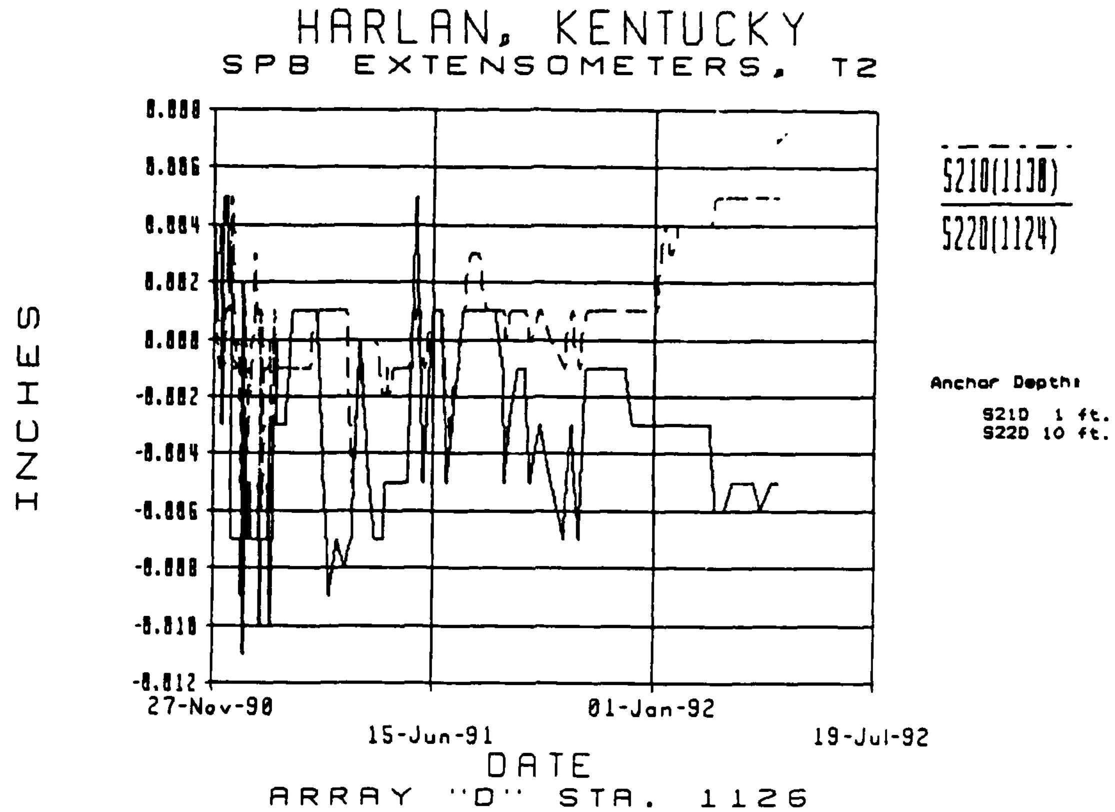


HARLAN, KENTUCKY
SPB EXTENSOMETERS, T1
INCHES
0.100
0.050
0.000
-0.050
-0.100
-0.150
14-Nov-90
02-Jun-91
19-Dec-91
06-Jul-92
DATE
ARRAY "C" STA. 1598
S17C(1600)
S18C(1602)
Anchor Depth:
S17C 8 ft.
S18C 1 ft.

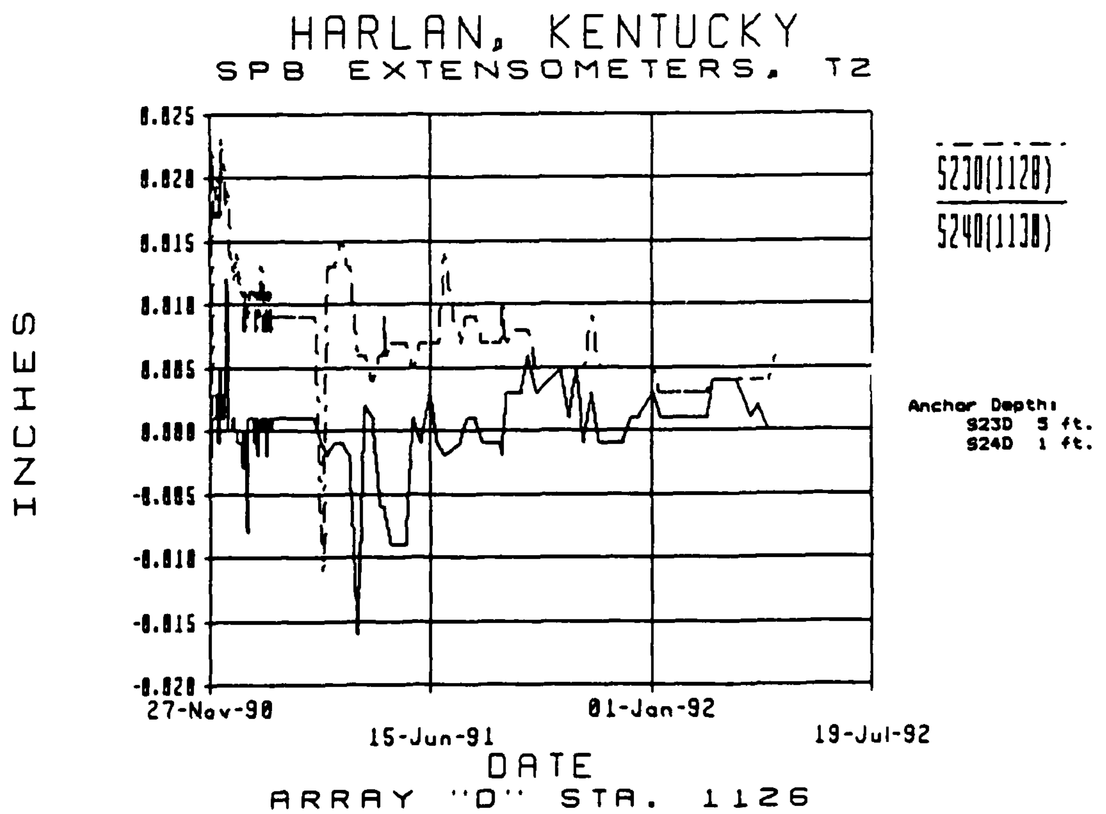


HARLAN, KENTUCKY
SPB EXTENSOMETERS, T2
INCHES
0.020
0.018
0.015
0.013
0.010
0.008
0.005
0.003
0.000
-0.003
-0.005
-0.008
-0.010
-0.013
-0.015
-0.018
-0.020
27-Nov-90
15-Jun-91
01-Jan-92
19-Jul-92
DATE
ARRAY "D" STA. 1126
S19D(1124)
S20D(1128)
Anchor Depth:
S19D 10 ft.
S20D 5 ft.

PLATE I-45



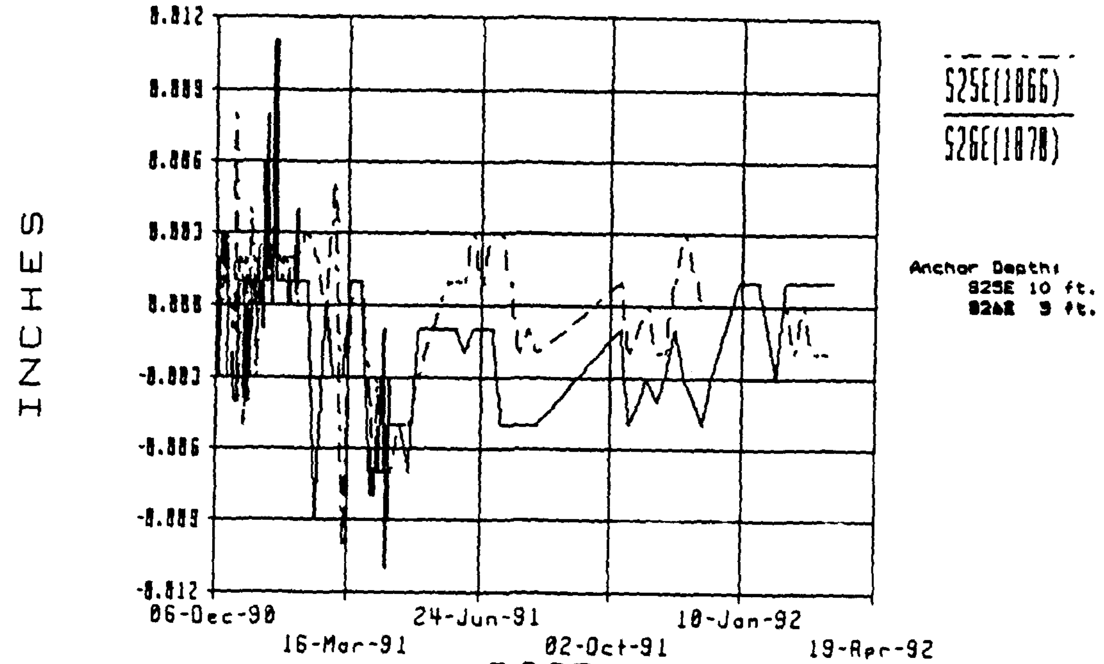
HARLAN, KENTUCKY
SPB EXTENSOMETERS, T2
INCHES
0.008
0.006
0.004
0.002
0.000
-0.002
-0.004
-0.006
-0.008
-0.010
-0.012
27-Nov-90
15-Jun-91
01-Jan-92
19-Jul-92
DATE
ARRAY "D" STA. 1126
S21D(1130)
S22D(1124)
Anchor Depth:
S21D 1 ft.
S22D 10 ft.



HARLAN, KENTUCKY
SPB EXTENSOMETERS, T2
INCHES
0.025
0.020
0.015
0.010
0.005
0.000
-0.005
-0.010
-0.015
-0.020
27-Nov-90
15-Jun-91
01-Jan-92
19-Jul-92
DATE
ARRAY "D" STA. 1126
S23D(1128)
S24D(1130)
Anchor Depth:
S23D 5 ft.
S24D 1 ft.

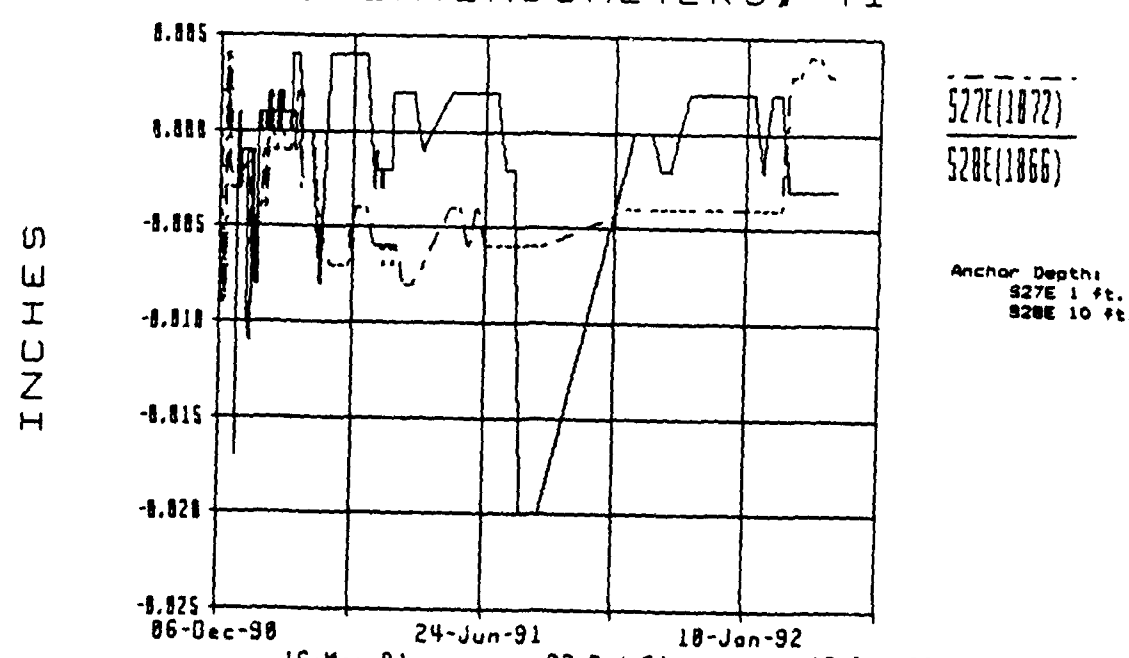
PLATE I-46

HARLAN, KENTUCKY
SPB EXTENSOMETERS, T1



DATE
ARRAY "E" STA. 1868

HARLAN, KENTUCKY
SPB EXTENSOMETERS, T1



DATE
ARRAY "E" STA. 1868

PLATE I-47

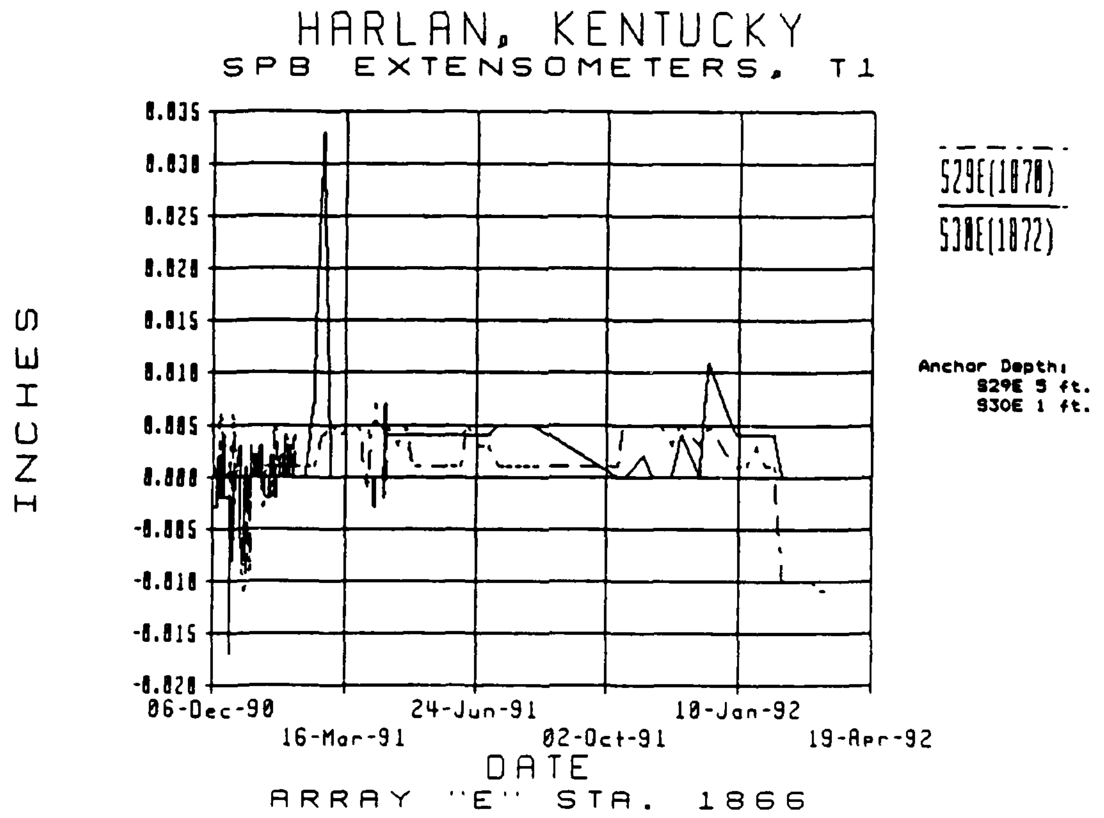

HARLAN, KENTUCKY
SPB EXTENSOMETERS, T1
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
-0.005
-0.010
-0.015
-0.020
INCHES
06-Dec-90
16-Mar-91
24-Jun-91
02-Oct-91
10-Jan-92
19-Apr-92
DATE
ARRAY "E" STA. 1866
S29E(1870)
S30E(1872)
Anchor Depth:
S29E 5 ft.
S30E 1 ft.

PLATE I-48